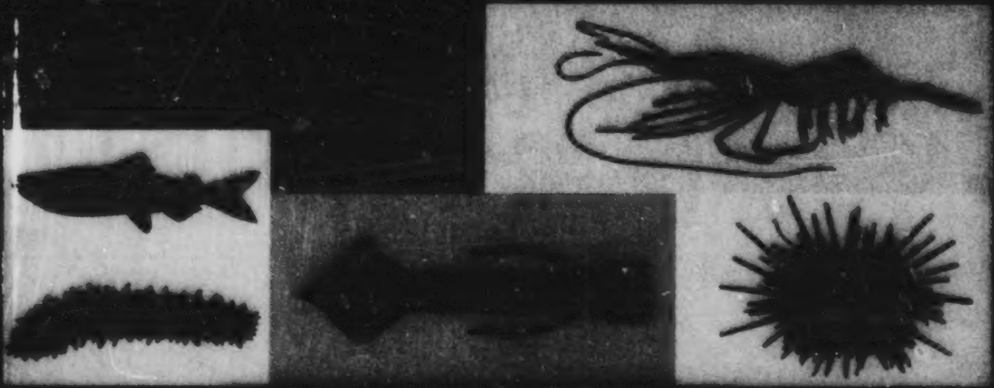
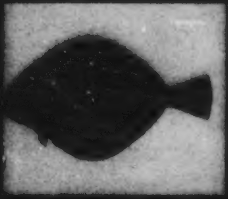
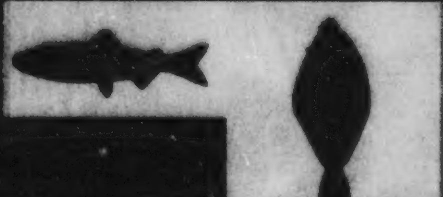


FISH STOCKS
OF THE PACIFIC COAST





Fisheries and Oceans
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FISH STOCKS
OF THE PACIFIC COAST

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Printed in Canada

For further information, or additional copies,
contact (604) 666-0384

ISBN 0-662-30042-4
Cat. no. Fs23-397/2001E

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102-04909/

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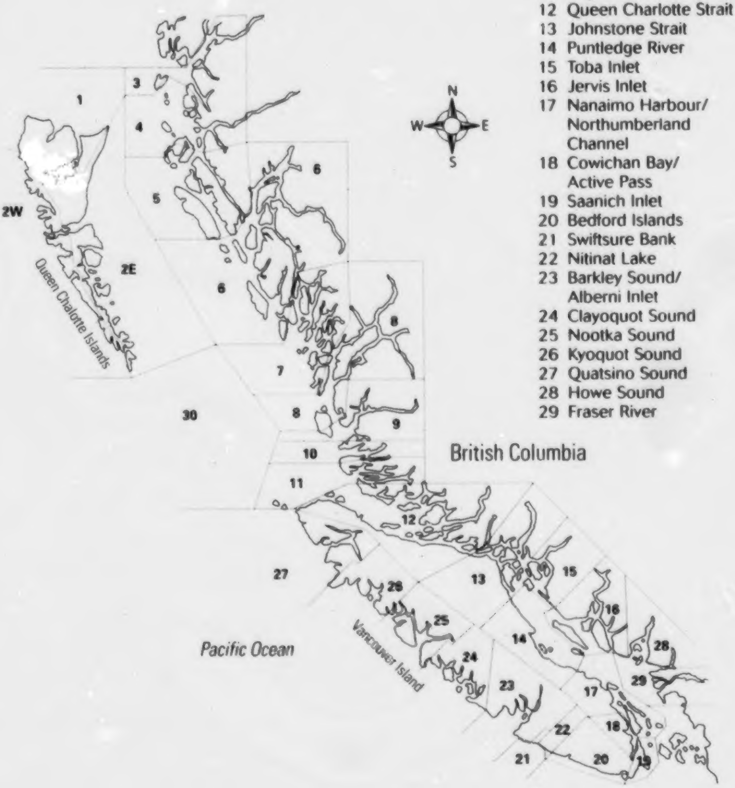
Northeastern Pacific Ocean

"Progress is being made toward a more responsible, sustainable management framework."

1. Masset Inlet
2. Queen Charlotte Island
3. Nass River
4. Skeena River
5. Hecate Strait
6. Kitimat River
7. Milbank & Mathieson Sounds
8. Burke Channel
9. Rivers Inlet
10. Cape Caution
11. Cape Scott
12. Queen Charlotte Strait
13. Johnstone Strait
14. Puntledge River
15. Toba Inlet
16. Jervis Inlet
17. Nanaimo Harbour/ Northumberland Channel
18. Cowichan Bay/ Active Pass
19. Saanich Inlet
20. Bedford Islands
21. Swiftsure Bank
22. Nitinat Lake
23. Barkley Sound/ Alberni Inlet
24. Clayoquot Sound
25. Nootka Sound
26. Kyoquot Sound
27. Quatsino Sound
28. Howe Sound
29. Fraser River



Introduction

The waters of the Northeastern Pacific Ocean are home to an enormous diversity of coastal marine life. Six hundred types of seaweed, 70 species of sea stars, and dozens of species of whales and fish are found there. The waters of Canada's west coast alone support more than 9,600 salmon stocks. This region's biological abundance sustained some of North America's most complex aboriginal societies for thousands of years. Then, as now, fish and shellfish have supplied vital economic and cultural resources for entire communities.

Pressure on these marine resources has grown to the point where only careful management can ensure the survival of both the ecosystems and the ways of life dependent on what was once considered a limitless resource. Of the world's 200 major fisheries, almost two-thirds have peaked or are in decline. Some of Canada's west coast fisheries face similar trends. As commercial catches of some salmon stocks have fallen to all-time lows, government regulators have implemented new measures, including selective fishing, to restrict catches. In some areas, entire fisheries have been closed. The recreational fishing industry, faced with severe closures in many coastal areas, has turned to catch-and-release practices and alternative fisheries. Furthermore, scientific studies show that climate change and ocean conditions, two factors beyond anyone's control, may have the greatest impacts of all.

Despite such impacts, fishing on Canada's west coast continues to employ thousands of people, retaining an important role in many of the region's communities. As the agency responsible for managing the fish stocks of this area, Fisheries and Oceans Canada must balance ecological, aboriginal, commercial, recreational and public interests along 27,000 km of coastline and in open ocean extending 320 km into the Pacific. The challenge is enormous. Fish populations are prone to irregular cycles in abundance and are vulnerable to unpredictable and uncontrollable environmental factors. Furthermore, the effects of fishing and other human activities, including logging, recreation and navigation, on fish and fish habitat can be significant and are sometimes poorly understood. Despite this variability and uncertainty, government managers make a wide range of resource management decisions to meet multiple and sometimes conflicting objectives.

Overall, progress is being made toward a more responsible, sustainable management framework. The 1990s saw both the fisheries and the regulations that govern the industry subjected to profound changes. For instance, Canada's Oceans Act now includes a precautionary approach and recognizes the need to manage entire ecosystems, rather than focusing solely on maximizing catches of individual species. Some stocks continue to decline despite these efforts, but others show signs of healthy, even dramatic, recovery. Today's fishing industry bears little resemblance to that of even 10 years ago – once valued catches are in decline, while many species of fish and shellfish once ignored or thrown back to sea as nuisance catches are now valuable fisheries.

Other changes include the growth of aboriginal fisheries, which have been bolstered by recent court decisions recognizing the rights of First Nations people to harvest marine resources for food, social and ceremonial purposes. This trend, along with newfound respect for traditional fishing techniques, is also playing a vital role in some conservation efforts. Also competing for public and government support is a relative newcomer on the scene – the aquaculture industry. Though provincial regulations have limited expansion of fish farming along Canada's west coast, the industry already produces more salmon annually than that caught by the commercial fleet each year.

The responsibility for balancing the complex demands made on the marine resources of Canada's west coast falls on federal government managers. Their decisions are based on biological research conducted by government and privately funded scientists, whose findings have been examined by the Pacific Scientific Advice Review Committee. The committee's recommendations are passed on to the Minister of Fisheries and Oceans, who is ultimately responsible for managing the species and the economies that depend on them.

Ensuring the health of a fishery entails much more than evaluating scientific evidence, however. The facts and figures that tell the story of each species must be considered in the larger context of other ecosystems in the changing Pacific ocean, as well as weighed against society's evolving cultural and economic needs.

The reports in this book are based on scientific research, which is an on-going process. As they work, scientists use the most up-to-date survey and analytic techniques to produce the best possible estimates of the size of fish stocks. They are also charged with predicting the effects of fishing on those stocks, no easy task when their subjects are species that migrate thousands of kilometres each year or live at inaccessible depths.

The quantity and quality of available research varies from species to species. Some reports are based on decades of records and observations, particularly those dealing with species that have a long history of commercial fishing. Other species have come to the attention of the fishing industry and the scientific community only in the past 10 – 15 years, so the depth of knowledge in these cases is relatively limited.

Overall, these reports do not answer all the questions posed by the demands of fisheries and oceans management. Instead, they represent a summary of what has been learned so far.

State of the Northeastern Pacific Ocean, 1998

Background

Water temperature, salinity levels, currents and wind-induced upwelling – all of these ocean conditions are in constant flux, especially when affected by significant changes such as long-term climate change, or the 1997–98 El Niño-Southern Oscillation (ENSO) event in the North Pacific. Such variations affect the marine food web which, in turn, impacts the fisheries that contribute so much to the economy and cultural heritage of Canada's west coast. Understanding the physical conditions and dynamics that shape the properties of the Northeastern Pacific, roughly defined as that portion of the Pacific Ocean north of 40°N latitude and east of 145°W longitude, is a vital first step toward understanding the distribution and abundance of the many marine species harvested in Canada's west coast waters.

Conditions in 1998

The years 1997 and 1998 were marked by unusually warm sea surface temperatures, low surface salinities, weak upwelling, favourable winds and diminished shelf-break currents off the west coast of Canada. These effects have been associated with the major 1997–98 El Niño-Southern Oscillation (ENSO) event in the North Pacific. This was the most intense ENSO event of the century. Beginning in April 1997, the effects of this event lingered well into the fall of 1998, long past its demise in the equatorial Pacific region.

The effects of the 1997–98 El Niño were felt across the ocean and in much of North and South America. In the Northeastern Pacific, sea surface temperatures were significantly higher than normal throughout the region, often exceeding all recorded values since observations began in the 1930s. Surface waters off the coast of Oregon increased to a record 18.5 C, a full degree warmer than recorded temperatures during the major 1982–83 El Niño event, and 5 C above those recorded in the 1970s. Other stations recorded temperatures 1 or 2 C above normal from the summer of 1997 through the spring of 1998. The monthly average temperature at Amphitrite Point near Ucluelet on Vancouver Island was 16 C in September 1997, topping the 1979 record of 14.9 C. Observations down the water column showed that the increase extended to over 50 metres depth and was not restricted to the top few metres. Lower salinities were recorded during this period, again primarily in the upper ocean layer.

During the same period, mean sea levels along the west coast of Canada were far above normal. During strong El Niño years, coastal sea levels can be expected to rise about 10-20 cm above seasonal heights, and such a rise was reported in the spring and summer of 1997. By February 1998, observed levels were 30 cm above normal. Further out to sea, at a Line P station in 1,300 metres of water, a dynamically induced sea level increase of 10 cm above any record collected since 1969 was reported.

Many of the extreme conditions associated with the 1997-98 ENSO event waned during the last half of 1998. However, there is increasing evidence that some of the deviations in conditions are more permanent and may be related to long-term climate change. Preliminary studies in the Northeastern Pacific suggest that the mid-winter surface mixed layer, the source of much of the nutrients on which many species of fish depend while in the open ocean, is about 25 per cent shallower now than it was 30 or 40 years ago.

This layer is the product of nutrient-rich cold and salty waters rising from the depths and mixing with sun-warmed fresh waters close to the surface. It provides an ideal habitat for phytoplankton, the organisms that form the foundation of the ocean food web. In recent years, the mixing process appears to have weakened, possibly because of increased precipitation falling on surface waters. As a result, concentrations of nutrients have fallen dramatically. Where nutrient levels once remained high for most of the year, the last 10 years have seen levels decline to perilously low levels. In spring of 1998, nutrient levels of zero were recorded along a line stretching more than 1,000 km west from the Strait of Juan de Fuca.

Changes in sea surface temperature, declining food supply and changes in food cycle timing are all likely having some effect on fish stocks, and those effects are sometimes more complex or subtle than simply a decline in survival. Among the more surprising findings in 1997 was the straying of some Fraser River sockeye during their spawning migration. From northern California and northern Vancouver Island, sockeye were found in unusual abundance in streams and rivers other than those in which they were spawned. DNA analyses show that some, though not all, of these fish belonged to stocks that originated in streams several hundred kilometres away. Researchers suspect these fish began their migration from a location further than normal from their spawning stream, or they took unusually long migration routes after encountering currents or conditions that altered their migration. By the time they had reached sexual maturity and were ready to spawn, they were still far from their natal streams, forcing them to divert to unfamiliar streams.

Not all the effects of the changing climate are negative. In the case of the Pacific sardine *(Sardinos sagax)*, conditions in recent years have led to increased numbers of fish whose numbers had precipitously declined since the 1940s. Until 1947, a lucrative sardine fishery operated on Canada's west coast. The collapse of the stock that year was once thought to be a classic example of the consequences of overfishing, but surveys and incidental catch figures from the last few years suggest a significant number of sardines are moving northward into Canadian waters, possibly as a result of warming waters. As sardines are considered an excellent indicator of ecosystem stability or change, it is now clear that ocean conditions affect both survival and distribution of such species.

Whales and other marine mammals are also important ecological indicators, and studies show several species of cetaceans are being affected by changing ocean conditions. Fin, humpback, minke, sei and northern right whales were observed shifting their historic distributions in 1997 following unusual phytoplankton blooms in the South Bering Sea. The phytoplankton, which serve as forage for both whales and whale prey, bloomed in waters not known for such biological activity, likely in response to increased surface temperatures. By the summer of 1997, sea surface temperatures in the region were two to four degrees warmer than in the previous year. The redistribution of whales is consistent with either a shift in foraging ecology linked to El Niño conditions, or a longer-term shift in regional productivity of the ecosystem.

For the kelp population on the west coast of Vancouver Island, warmer waters have produced an opposite effect. Barkley Sound surveys of the population density of dominant intertidal species of kelp (*Hedophyllum sessile*) conducted between 1991 and 1998 showed reproduction rates decreased sharply during the 1997–98 El Niño event. June 1997 was the first summer during the survey when there was no recruitment of juvenile individuals to the kelp beds. Extremely low adult densities in May 1998 may be a result of the same factors, but the most recent data show the population is recovering.

Some seabirds were subjected to similar pressures during 1997–98. A monitoring program along Line P in 1996, 1997 and 1998 found that both the overall total density and the diversity of species were the lowest in June 1997, when the highest sea-surface temperatures were recorded. Counts from 1998, however, show that diversity levels have returned to normal.

Note: For a thorough reference to B.C. coastal and open-ocean oceanography, consult "Oceanography of the British Columbia Coast" by R.E. Thomson, 1981; Can. Special Publication of Fisheries and Aquatic Sciences.

State of the Northeastern Pacific Ocean, 2000

Background

As described in the previous chapter, the physical, chemical and biological state of the ocean impacts the yield of marine organisms as well as the fishing industry so vital to Canada's west coast. Because of the importance of environmental changes on marine resources, extensive data are collected from a variety of sources, including research vessel surveys, coastal light stations, subsurface current meters and satellite remote sensing. Observations made onboard commercial ships and fishing vessels are also important.

Data gathered for 2000 showed that conditions in the Northeastern Pacific reflected the moderate La Niña conditions occurring in the equatorial Pacific. The El Niño-Southern Oscillation (ENSO) events of 1997-98 were quickly followed by a La Niña event beginning in the fall of 1998 and continuing through most of 1999. Since then, the La Niña event has shown signs of disappearing, and then returning. The result was that, though not as severe as in the winter of 1998-99, the winter of 1999-2000 and subsequent seasons were dominated by ocean temperatures significantly below normal. Several indicators suggest that in early 2001, the Pacific Ocean was near normal on the equator, where El Niños and La Niñas are formed, and that a moderate El Niño warming event

Conditions in 2000

The moderate La Niña conditions in the equatorial Pacific in 2000 meant that, for the most part, sea surface temperatures in the Northeastern Pacific were normal to below normal. Throughout the Gulf of Alaska, except for a large, persistent pool of warm surface water centered near 35°N, 160°W, sea surface temperatures were approximately 1 C lower than normal. Anomalously low temperatures penetrated to about 100 m depth. On the North Coast in 2000, as in 1999, sea surface temperature out to 50 km west of the continental shelf was slightly cooler than the long-term average. Off the west coast of Vancouver Island, coastal and continental shelf sea surface temperature varied from near normal to roughly 0.5-1.0 C below average, while sub-surface temperatures to 400 m were normal to slightly below normal, with one exception. At a site off Estevan Point in later summer sub-surface temperature was much higher than normal. In the Strait of Georgia, sea surface temperatures at the sea surface and at mid-depth were close to the long-term average throughout the year.

As indicated by the sea levels at the ports of Victoria, Tofino and Prince Rupert, sea levels were generally normal for the year and appreciably lower than the high sea levels observed during the 1997-98 El Niño. The annual average sea levels on the North Coast for 2000 were lower than the long-term trend. The west coast of Vancouver Island experienced normal upwelling in summer 2000, and persistent downwelling conditions during the winter of 1999-2000 and the fall of 2000.

After the low surface salinities of the 1997-98 El Niño conditions, salinities in the Northeastern Pacific were generally near normal in 2000. Salinity in the Gulf of Alaska was, unlike 1999, very close to the long-term normal. On B.C.'s North Coast surface salinities at Bonilla Island in Hecate Strait were close to or slightly above the long-term average, while Langara Island in Dixon Entrance continued to show a decreasing salinity trend. On the west coast of Vancouver Island, sub-surface salinities to 400 m depth were near normal, with two sites experiencing periods of much lower salinity in spring and early summer. In the Strait of Georgia, salinities were normal for most of the year. However, along with reduced rainfall, there was an indication of higher than normal salinities at the end of 2000 and continuing into 2001.

In addition to the measurements of the physical ocean environment, observations at various levels of the marine food chain – from nutrients through plankton to fish and higher level predators – are made to understand the impact of changes in the physical environment. Observations of the lower levels of the marine food chain indicate a return to normal levels of nutrients (nitrate) and phytoplankton.

Improved conditions off the west coast of Vancouver Island in 2000 brought a substantial increase in the zooplankton prey species for herring, hake and coho salmon. Improved food availability for these fish removes the constraint on growth and marine survival which characterized recent years. The increased food availability for coho salmon suggests that marine survival rates should be high for fish returning in 2001. However, in 1999 and 2000, total catches of Pacific salmon in Canada were the lowest on record (since 1925). This is thought to reflect the impacts of poor ocean conditions for these fish earlier in their life history. Catches in 2001 are expected to remain low, but indicators show that future productivity will improve in the salmon's southern range. For herring, apart from predation, ocean conditions were more favourable in 1999 and 2000, and should result in improved recruitment to the stock in the year 2002.

In 2000, Pacific sardines (Sardinos sagax), a migratory species, did not appear in Canadian waters until late July and early August, and were confined to coastal inlets along Vancouver Island. Hake abundance also dropped off dramatically during the year They were not found in traditional fishing grounds, but rather only in small aggregates off the north coast of Vancouver Island.

Coho abundance in the Strait of Georgia increased significantly in 2000, reaching levels nearly double those of 1999. Strait chinook and chum salmon populations saw a marked increase as well. Herring populations were similar to those of the last several years, which is slightly above the historically estimated levels. The year 2000 also saw in the strait a significant increase in euphausiid size and biomass – the number of euphausiids in fall 2000 was double that of the previous year. Since euphausiids are a major source of food for many predators, including coho, this bodes well for future populations. Determining the exact mechanisms for these changes is the subject of active research.

The situation with grey whales along Canada's west coast in 2000 was similar to 1999. A number of grey whales were found washed up dead along the coast, emaciated and apparently having run out of food reserves. This may have been linked to inadequate feeding in the Bering Sea in the summer of 1999. In contrast, humpback whales were particularly abundant especially around the Scott Islands at the north end of Vancouver Island, where more than 100 humpbacks were observed feeding around Cox Island. Sightings of humpback whales were also common along the Queen Charlotte Islands.

Triangle Island, off the north coast of Vancouver Island, supports the world's largest population of Cassin's auklet (*Ptychoraamphus aleuticus*), as well as rhinoceros auklets (*Cerorhinica monocerata*), tufted puffins (*Fratercual cirrhata*) and common murres (*Uria aalge*). These bird populations have been studied since 1994. In 2000, the seabirds breeding on Triangle Island performed well, which was similar to the 1999 season. For the tufted puffin and Cassin's auklet, nestling growth rates were strikingly similar to the high levels observed in 1999.

Climate Change and the Northeastern Pacific Ocean

Suspicions that the earth is warming have dominated climate research for most of the last 15 years. In 1995, the United Nations Intergovernmental Panel on Climate Change, composed of 2,500 of the world's leading researchers on the subject, concluded that "the balance of evidence suggests a discernible human influence on global climate." In other words, industrial activities are at least partly responsible for heating up the planet's atmosphere, lands and oceans.

Since 1995, scientists have continued to gather evidence that supports climate change theories. Data collected from the Pacific Ocean, including records of daily surface temperatures on Canada's west coast that stretch back to 1915, are no exception. The world is about 0.7 C warmer today than a century ago and the latest computer models predict that, without drastic cutbacks in emissions of carbon dioxide and other gases released by the burning of fossil fuels, the average global surface temperature will rise by another two degrees in the 21st century.

Much of that increase will likely occur in the oceans, and evidence suggests that the most dramatic changes in ocean temperature are now occurring in the Pacific. Coastal environments, meanwhile, are expected to feel the effects of increased run-off from melting glaciers. For example, in 1998, the Strait of Georgia was one degree warmer than it was 20 years ago.

The threat of rising sea levels is among the most commonly cited examples of the effects of global warming, but more subtle changes are already being felt by fish and other species that dwell in the waters that cover more than 70 per cent of the earth's surface. Though debate persists over the cause of some of the changes, scientists agree that the effects on salmon, for one, are already evident.

Fisheries and Oceans Canada research teams studying the Northeastern Pacific have discovered that the mid-winter mixed layer of waters near the ocean's surface – the source of much of the nutrients on which salmon live while in open seas – is about 25 per cent shallower now than it was 30 or 40 years ago. The layer results from the mixing of cold and salty waters rising from the depths and sun-warmed fresh waters close to the surface. It provides an ideal habitat for the organisms that form the foundation of the ocean food web. In recent years, however, the mixing process appears to have weakened, possibly because of increased precipitation falling on

Possible effects of climate change

- Sea levels are expected to rise by as much as 30 cm on the north coast of B.C. in the next century, mainly due to warmer ocean temperatures, which lead to thermal expansion much the same way that hot air expands. This could cause increased sedimentation, coastal flooding and permanent inundation of some natural ecosystems, possibly placing low-lying homes, docks and port facilities at risk.
- In winter, increased winter precipitation, permafrost degradation and glacier retreat due to warmer temperatures may lead to landslides in unstable mountainous regions, and put fish and wildlife habitat, including salmon-spawning streams, at risk. Glacier reduction could affect the flow and temperature of rivers and streams that depend on glacier water, with potential negative impacts on fish habitat.
- Summer droughts along the south coast and in the southern interior of B.C. will mean decreased stream flow in those areas, putting fish survival at risk and reducing water supplies in the dry summer season when irrigation and domestic water use are greatest.
- Changes in ocean currents will lower temperatures and force species that require cooler waters to travel further north, increasing migration times and reducing the fish's ability to reach spawning grounds

surface waters. As a result, concentrations of nutrients have fallen dramatically. Where nutrient levels once remained high for most of the year, the last 10 years have seen levels decline. In the spring of 1998, Fisheries and Oceans Canada scientists recorded a nutrient level of zero along a line stretching west from the Strait of Juan de Fuca more than 1,000 km.

The consequences for migrating salmon, which are extremely sensitive to even slight changes in the temperature of their environment, are significant. Though most salmon research has focused on the freshwater phase of the fish's life cycles, studies of sockeye, steelhead and coho populations have already turned up evidence of the effects of declining ocean nutrient levels. As salmon swim home to their spawning beds, it is thought they now travel through what amounts to an ocean desert. Feeding stops and behaviour patterns are disrupted. Some salmon have been seen migrating into the wrong rivers – Fraser River sockeye heading up rivers on the west coast of Vancouver Island, for instance – and measurements of size and fat content have confirmed fishermen's reports that returning salmon appear to be in poor physical condition.

The changes in habits and health could be due to starvation, but it could also be a more direct result of warmer waters, which lead to increased metabolic rates. In either case, the consequences for some stocks are serious. Salmon do not feed while swimming upstream and so must rely on fat accumulated while in the open ocean. If they start their river runs with low fat levels, they are more likely to die before reaching their spawning grounds.

The relationships among atmospheric carbon dioxide concentrations, ocean temperatures and nutrient levels present challenges for oceanographers and biologists, but they are only part of the picture. Complicating matters further are irregular phenomena such as El Niño and La Niña, ocean current changes of unclear origins in the tropical Pacific but with worldwide consequences for weather patterns. The frequency of El Niño and La Niña events could also be affected by climate change.

The relatively recent discovery that abrupt changes in the local climate and productivity of the North Pacific occur every few decades has introduced yet more uncertainty into the scientific debate. The physical effects of these regime shifts can be dramatic, but what role they play in abundance levels of fish stocks is the subject of much debate. One possibility is that salmon will retreat northwards as the oceans warm. By the time the salmon complete what will be lengthier migrations to spawn, they will be weaker and fewer in number.

At the same time, not all of the changes in climate necessarily lead to declining fish stocks. Some scientists suspect a regime shift was responsible for the increase in numbers of sardines and hake off the west coast of Vancouver Island in 1998. In the past, a change in sardine populations was accompanied by similar changes in salmon, but that link may no longer be in effect. Others say that the evidence points to a natural population cycle operating since the last ice age, one that has nothing to do with climate.

Sorting out which changes in fish populations are the result of long-term climate change, regime shifts or shorter term weather patterns presents enormous challenges.

In addition to the ecosystem, scientists must also consider genetic and behavioural changes in fish stocks, the causes of which are even less obvious, as well as impact from fishing and the condition of spawning habitat. In many cases, fish abundance forecasts beyond a year or two are nearly impossible to make with any useful degree of confidence. Scientists have been able to agree, however, that the global climate, including that of the Northeastern Pacific Ocean, is changing, and that those changes are important to the future of fish populations.

Aboriginal Fisheries

First Nations fisheries pre-date the advent of modern governmental authorities, and often supplied the cornerstone of the First Nations diet along Canada's west coast. These fisheries are protected by the Canadian Constitution and are recognized by the Supreme Court. Conservation is the primary priority of fisheries management policy of Fisheries and Oceans Canada. Once conservation requirements are satisfied, the food, social and ceremonial allocations of west coast First Nations are addressed.

The federal Aboriginal Fisheries Strategy (AFS), established in 1992 to enhance aboriginal participation in the fishery and its management, incorporates several objectives:

- To provide aboriginal communities with opportunities to fish for "food, social and ceremonial" purposes, as laid down by the Supreme Court of Canada in what is known as the Sparrow decision of 1990.
- To provide a role for the aboriginal community in the management of aboriginal fisheries, which is done through agreements on co-operative fisheries management and economic development opportunities for First Nations, as well as pilot projects for the sale of fish.
- To avoid disruption of non-aboriginal fisheries through the voluntary retirement of commercial fishing licences, transfer of fish allocations to aboriginal communities for pilot sales projects, and issuing of commercial fishing licences to those communities.

The AFS involves the signing of one-year and multi-year agreements to enable First Nations people to participate in the co-management of the fishery in areas where there are no aboriginal or treaty rights outstanding. The agreements are not the equivalent of treaties as defined by the Constitution, but their provisions may be considered in any future treaty negotiations between First Nations, the federal Crown and provincial or territorial governments.

The west coast offers a unique situation as, unlike most of Canada, it was never subjected to large-scale treaty negotiations in the early years of the country. Only a few First Nations on Vancouver Island and the Dene of the northeastern corner of B.C. signed treaties with the federal government, leaving most of the coast without a negotiated relationship to the Crown.

In the Pacific Region, implementation of the AFS has resulted in the production of agreements with B.C. and Yukon aboriginal communities since 1992. Fisheries and Oceans Canada contributes annual funding of approximately $16 million to some 65 First Nations for use in habitat enhancement, catch monitoring and enforcement, fish management, community research, community awareness and economic development.

The Sparrow decision remains the cornerstone of federal fisheries policy in the Pacific Region. In addition to giving First Nations fishers a right to harvest fish for food, social and ceremonial purposes, the ruling gave these needs priority over any interests other than conservation.

However, aboriginal participation remains a constantly evolving element in the management of Canada's fisheries, and lower courts have come to differing conclusions on the issue. Some courts have ruled that First Nations rights to natural resources should not be limited to food and cultural needs. The B.C. Court of Appeal, meanwhile, has ruled that the sale of fish is not integral to distinctive aboriginal culture. As a result, commercial activities by First Nations fisheries now operate on the same terms and are subject to the same restrictions as non-aboriginal participants.

The Supreme Court has emphasized that the issue of sales should be addressed through negotiations, a ruling that ultimately led to the creation of the AFS. The Supreme Court's subsequent Delgamuukw decision in 1997, which dealt with aboriginal title to lands not covered by treaties, reaffirmed that negotiated agreements are preferable to litigated solutions. In effect, the AFS has been given judicial endorsement as the best route to resolve disputes over aboriginal resource rights, including fishing.

Regardless of the judicial context, First Nations people of Canada's west coast are not restricted to fishing for food, social and ceremonial purposes. In fact, a large portion of the commercial fishery employs aboriginal people aboard fishing fleets and in processing operations. In addition, First Nations people have been among the most committed participants in the revival and introduction of selective fishing technologies, such as fishing wheels, weirs and traps, many of which are adapted from methods used by aboriginal fishers long before modern equipment was introduced. Many First Nations are also involved in fish habitat restoration as well as the integration and modification of logging practices to ensure habitat preservation.

Selective Fishing

It has become clear that quotas alone may not ensure the survival of all stocks of a species. Because fish stocks often mingle in the open ocean, fish from a threatened stock are regularly caught by fishers seeking stocks which are in greater abundance. Even a ban on fishing a particular stock will not guarantee the recovery of a severely weakened population unless some way is found to prevent the unintended harvesting, known as bycatch, that is almost inevitable in conventional mixed-stock fisheries. For example, coho salmon from the Thompson and Upper Skeena rivers may be intercepted by chum salmon fishing fleets. Even with fishing restrictions, some stocks of coho will remain at low survival levels until 2005 or 2007.

In the past, fishery management response to the bycatch problem sometimes involved shutting down entire fisheries. This caused hardship to sectors of the industry harvesting species and stocks that were still abundant. Clearly, an alternative to blanket bans on fishing was needed to meet both conservation and economic objectives.

The answer to this challenge, and the new cornerstone of the federal management strategy, is known as selective fishing. Announced in May 1998, selective fishing represents a fundamental change to the Pacific fishery, one that allows fishers from all sectors to continue to harvest more abundant stocks while reducing bycatches and protecting weaker stocks. Though many selective techniques are still experimental, they are putting Canada's fisheries at the forefront of new conservation initiatives while addressing growing global concern over bycatch of non-target species. Without selective fishing, it may not be possible to contribute to the survival of many fish stocks or the communities that rely on those fisheries.

Since 1998, with the co-operation of First Nations, commercial and recreational fisheries, a variety of selective fishing techniques has been tested on Canada's west coast. The methods take advantage of research that has improved our understanding of the behavior of many fish species, as well as the latest advances in fishing gear design. Together, the techniques are designed "to avoid, or release unharmed, non-target stocks or species of concern."

In the seine fleet, it is possible to use dipnets to remove target species from purse seines as the nets are closed, and then release the non-target species unharmed. Seine fleets can be prohibited from fishing in areas where non-target species are known to be abundant ("hot spot closures") or during those periods of the season when non-target species are most frequently observed ("timing closures"). Seine nets can be constructed of softer webbing, which reduces abrasion on non-target fish and increases their chances of survival.

Gillnet fleets can employ many of the same time and area closure techniques used by seine fleets. They can also restrict their fishing activities by not casting their nets during those times of the day or night when non-target species are more commonly caught. Instead of setting nets for up to several hours, gillnetters can also practise "hot picking", which requires nets to be pulled in shortly after being set so that non-target species can be released sooner, enhancing their chances of survival.

Troll fleets and recreational fishers can use barbless hooks, which improve survival rates of fish released after being caught. Time and area closures are also useful for selective troll fishing.

In addition to the time and area closures and other techniques being explored by commercial fleets, First Nations fishers are engaged in a variety of experiments designed to test alternative fishing techniques. These include using beach seine nets, weirs and fishing wheels. Many of the techniques involve harvesting salmon close to their spawning grounds, where different stocks can be more easily separated. A

Fisheries and Oceans Canada study found that the majority of such a catch was of sufficiently high quality for a broad range of smoked and canned products.

The fishing wheel is not a new technology, but one used extensively to harvest salmon in the 19th century. They were common on B.C. rivers until the 1930s, when conventional boat-based net fisheries successfully lobbied for their removal. Today, they are still used in Yukon and Alaskan rivers to harvest chinook, chum and coho.

Fishing wheels offer one of the more promising and ingenuous techniques for river-based fisheries. Powered by the current, the wheels consist of rotating baskets that scoop fish from the water as they swim beneath a floating platform and then slide the fish into a holding pen. From there target fish can be removed with a dip net while non-target species are freed to continue unharmed, having spent only seconds out of the water. Fishing wheels have been used in the Nass and Skeena rivers for more than 10 years. In addition, experimental operations run by First Nations and funded by Fisheries and Oceans Canada were set up last year in the Fraser River.

Weirs (wooden fences shaped like funnels and erected across rivers) offer another method for fishers to harvest only those species that can tolerate a fishery. Like fishing wheels, weirs divert fish to holding pools, where they can be sorted.

The Skeena River is the site of the most developed use of beach seine nets, in which nets are cast and hauled in from the riverbank. In 1997, more than 20 per cent of the total catch on the Skeena employed selective techniques, primarily beach seines.

When the Minister of Fisheries and Oceans unveiled selective fishing objectives in 1998, it was agreed that 5 per cent of the total allowable catch of Pacific salmon stocks would be set aside to test selective techniques and gear. To accelerate development of selective fishing techniques, Fisheries and Oceans Canada released a policy framework and announced in May 1999 that funding incentives and technical support would be available until 2001. The Canadian Fishing Adjustment and Restructuring Program contributed $1 million in 1999 to First Nations, recreational and commercial organizations to develop selective fishing and an additional $500,000 in 2000. By 2001, responsibility for further development will reside with the harvesters themselves. As the techniques are proven, commercial allocations will favour those fisheries demonstrating an ability and commitment to fish selectively.

Marine Mammals

Humans are not the only fishers of Canada's Pacific waters. At least two dozen species of marine mammals also ply the coast in search of salmon, herring, clams and many other sources of food. In effect, people are competing with whales, dolphins, seals, sea lions and sea otters for finite resources. Fisheries and Oceans Canada is responsible for managing both fish and marine mammals, and for striking a balance among these competing demands. Because the federal Oceans Act calls for government scientists to consider entire ecosystems rather than taking a species-by-species approach when managing marine resources, the needs of marine mammals must be considered.

Research is underway to improve our understanding of how marine mammal populations affect fish stocks. In some cases, scientists have found that seals and sea lions are proving to be tough competitors for commercially valuable stocks, leading some fishers to suggest population controls. Unfortunately, much remains unknown about the dietary habits of many species of marine mammals. Interactions among members of the marine food web are extremely complex, and any efforts to control marine mammal populations must be carefully evaluated.

Marine mammal research is a difficult field, and many questions remain unanswered, particularly on species at risk. Minimum viable population sizes are often in doubt, as is the tolerance of many species to environmental disturbances such as oil spills.

Killer Whales

The most familiar marine mammal in Canada is the killer whale (*Orca orcinus*), also known as the orca and scientifically considered a member of the dolphin family. Though often used as a symbol of Pacific northwest culture and considered the most popular whale attraction in aquariums, the killer whale is facing an uncertain future.

Studies suggest that only a few hundred killer whales live in the Northeastern Pacific. In 1999, the Committee on the Status of Endangered Wildlife in Canada added west coast killer whale populations to its list of species at risk. Northern and southern "resident" killer whales, which eat only fish, were designated as threatened with an estimated total population of 300 in Canada's west coast waters. The "transient" population, which dines primarily on seals, otters and other marine mammals, was given the less dire but still serious designation of vulnerable. An estimated 219 transients have been identified in the region.

Resident and transient populations, which support a growing whale-watching industry, frequent the waters off the eastern and western coasts of Vancouver Island. Less is known about a third population of orcas, the off-shore killer whales. They are most often seen near the Queen Charlotte Islands, but occasionally have been sighted close to Victoria on Vancouver Island.

The killer whales found in Canada's west coast waters are among the most studied marine mammals in the world, due in part to the unique markings on their dorsal fins that permit photo identification. Most of these orcas have been given their own alphanumeric names and have had their family structures mapped out.

Grey Whales

Because of federal and international protection, marine mammals found in Canada's west coast waters are no longer hunted and several species are showing signs of recovery. The best example is the grey whale (*Escherichtius robustus*). Hunted almost to the point of extinction earlier this century, grey whales were given international protection in 1946. Since then, Pacific populations have rebounded from about 2,000 to more than 26,000 individuals, a level comparable to pre-whaling numbers.

Each spring, thousands of grey whales migrate past Vancouver Island on their way to summer feeding waters off the coast of Alaska. A few hundred grey whales remain near Vancouver Island all summer, rejoining the rest of the herd as it heads south each winter. The island's whale-watching industry depends on the greys today much as whalers of the past once did. Although the possibility of an aboriginal hunt for grey whales remains a contentious issue, a revival of the commercial hunt in Canadian waters is not being considered.

While grey whale populations have rebounded, other species of whales found in Pacific waters are considered to be at risk. The northern right whale (*Eubalaena glacialis*), now rarely seen in the area, is listed as endangered, the highest level of concern. As few as 100 may be left in the Pacific Ocean. The humpback whale (*Megaptera novaeangliae*) is considered threatened in the Pacific, and the northern bottlenose whale (*Hyperoodon ampullatus*) is listed as vulnerable.

Sea Otters

Sea otters (Enhydra lutris) were wiped out earlier this century but then re-established on the west coast of Vancouver Island through an experimental program begun 30 years ago. They are on the threatened list but are increasing in numbers.

The case of declining sea otter populations illustrates the degree of complexity facing government managers. One recent study suggests that overfishing of pollock in Alaskan waters, combined with changing ocean temperatures, is responsible for the collapse of sea lion populations, which feed primarily on pollock. Sea lions constitute a major source of food for transient killer whales and as a result, sea otters have replaced sea lions in the killer whale diet. Unfortunately, sea otters are smaller and contain less fat than sea lions, providing a poor source of nutrition for whales.

Heavy predation of sea otters has lead to still more changes in the marine ecosystem. Most notable is a population explosion of one of their main prey, sea urchins, which in turn devastate kelp beds, used by some species of whales as safe havens for their calves.

Sorting out how much of the sea otter's decline is due to killer whale predation and how much to environmental changes presents an enormous challenge to biologists. Even healthy populations of marine mammals, such as the Pacific white-sided dolphin (Lagenorhynchus obliquidens), are difficult to study. Though the white-sided dolphin is not considered at risk and may even be growing more common in inshore waters, little is known of its life history. Recent surveys found some 38,000 off the coast of Oregon and Washington, but there are no reliable estimates of how many reside in Canadian waters.

Marine mammals found in the Northeastern Pacific:

Whales
- Blue whale
- Fin whale
- Sei whale
- Grey whale
- Sperm whale
- Humpback whale
- Northern right whale
- Baird's beaked whale
- Cuvier's beaked whale
- Minke whale

Dolphins and Porpoises
- Killer whale (orca)
- False killer whale
- Short-finned pilot whale
- Risso's dolphin
- Northern right whale dolphin
- Dall's porpoise
- Common dolphin
- Harbour porpoise
- Pacific white-sided dolphin

Pinnipeds
- Northern elephant seal
- Steller's sea lion
- California sea lion
- Northern fur seal
- Pacific harbour seal

Sea otter

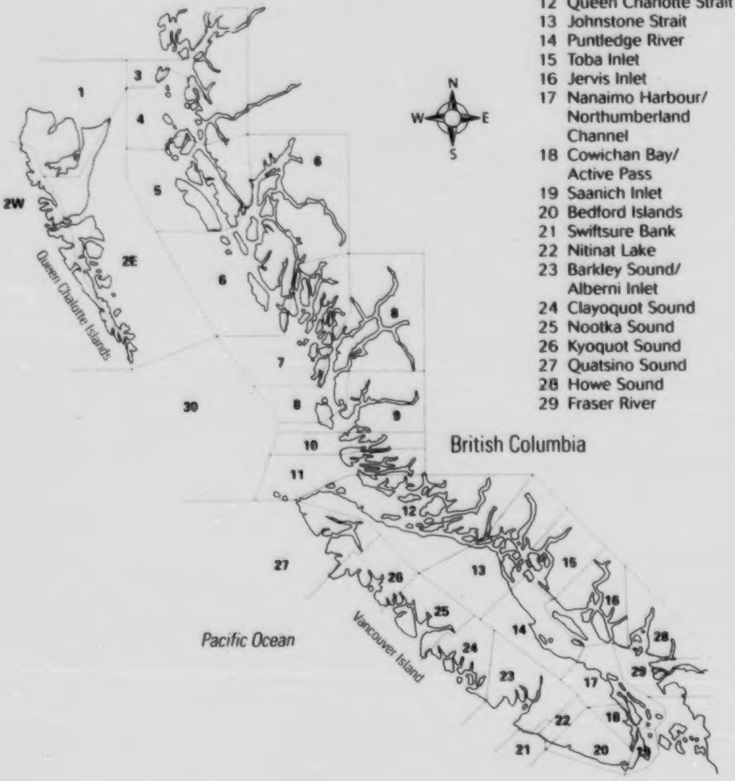
Salmon of the Pacific

Management Areas

Northeastern Pacific Ocean

"Scientists have identified more than 9,600 salmon stocks in Canadian west coast waters."

1	Masset Inlet
2	Queen Charlotte Island
3	Nass River
4	Skeena River
5	Hecate Strait
6	Kitimat River
7	Milbank & Mathieson Sounds
8	Burke Channel
9	Rivers Inlet
10	Cape Caution
11	Cape Scott
12	Queen Charlotte Strait
13	Johnstone Strait
14	Puntledge River
15	Toba Inlet
16	Jervis Inlet
17	Nanaimo Harbour/ Northumberland Channel
18	Cowichan Bay/ Active Pass
19	Saanich Inlet
20	Bedford Islands
21	Swiftsure Bank
22	Nitinat Lake
23	Barkley Sound/ Alberni Inlet
24	Clayoquot Sound
25	Nootka Sound
26	Kyoquot Sound
27	Quatsino Sound
28	Howe Sound
29	Fraser River



Salmon of the Pacific

For thousands of years, the history, economy and culture of Canada's west coast have been inextricably linked to Pacific salmon. These magnificent fish have been an important part of both the diet and culture of First Nations people. When Europeans settled on the west coast, salmon fishing as an industry began, and by the 1870s, commercial fishing was well underway as canned salmon, especially sockeye, was in demand world-wide. Salmon, particularly chinook and coho, also play a key role in the west coast's recreational fishery.

Of the six species of Pacific salmon, only one, the masu (*Oncorhynchus masou*) originates exclusively in Asia. The other five species are found in both Asian and North American waters and comprise the mainstay of Canada's west coast salmon fishery. These are: chinook (*Oncorhynchus tshawytscha*), chum (*Oncorhynchus keta*), coho (*Oncorhynchus kisutch*), pink (*Oncorhynchus gorbuscha*) and sockeye (*Oncorhynchus nerka*).

Pacific salmon are anadromous, spawning in fresh water, but spending part of their adult lives in the ocean. They may range from the shores of Asia to the coast of North America as far south as California and as far north as the Arctic Ocean. Depending upon the species, they spend from one to seven years in the Pacific before returning to their freshwater natal streams to spawn, some swimming as far as 3,200 km from the sea. Physical characteristics, life histories and spawning habits vary from species to species. Total life spans range from two years (for pink) to eight years (for some sockeye and chinook).

In Canada, Pacific salmon are managed by Fisheries and Oceans Canada and the International Pacific Salmon Fisheries Commission. The vast number of stocks and the complex life cycle of these fish present substantial management and research challenges. Scientists have identified more than 9,600 salmon stocks in Canadian west coast waters, of which close to 5,500 have been assessed.

Producing estimates of the population of each salmon stock is complex. Not all stocks of one species share the same cycle length. Complicating matters further, the size of some "year-classes", as the stocks born in each year are known, can vary greatly from one year to the next. For example, species with a two-year cycle may produce much larger populations in even-numbered years than in odd-numbered years.

Taking these cycles into account, scientists use a variety of techniques to estimate the number of salmon in a given stock. For some stocks, the number of juvenile "recruits" that join the adult population each year are counted. In others stocks, the number of females counted along spawning beds produce more reliable data. Another method entails the tagging or marking of salmon. When these fish are caught, the information is reported to Fisheries and Oceans researchers, who use the data to estimate the size of the stock population. For most species, several methods are used to generate the estimates and forecasts found in these reports.

As each stock is considered a separate population, subject to unique environmental and harvesting pressures, the salmon profiled in this section are categorized by both species and geography.

CHINOOK SALMON

Of the six Pacific salmon species, chinook (*Oncorhynchus tshawytscha*) have one of the most complex and diverse life cycles. There are two major life-cycle types: "stream" and "ocean". Stream-type chinook typically spend their first one or two years in fresh water before migrating to sea. This freshwater residency may be spent in the natal stream or, in the case of stocks in tributary systems, in the mainstem river.

After emerging from the gravel beds of their natal streams, ocean-type fish will typically spend no more than 90 days in fresh water before migrating to sea. Chinook salmon then spend one to six years in the ocean before returning to their natal streams to spawn. Thus, returning mature adults can be anywhere from two to seven years old. It is not unusual for spawning runs to be composed of five different age classes. Each stock has a specific run timing that can vary from early spring to mid-fall, and last from several weeks to months. Similarly, spawning times can vary from May to December, lasting from several weeks to months.

Chinook salmon spawn in large rivers from California to Alaska. They are found in a relatively small number of streams in B.C., with the bulk of production coming from the major river systems, the most important of these being the Fraser. Chinook are known to migrate vast distances, and are found sparsely distributed across the Pacific Ocean from 41°N to 60°N, and from the Okhotsk to Bering seas. They are frequently dubbed "spring" salmon because they return to some rivers earlier than other Pacific salmon species. In the Fraser and Columbia rivers, the early run starts in April.

A favourite of the sport fishery, chinook are the largest of the salmon species found on Canada's west coast. The world record is 57.27 kg, while chinook spawning after three or four summers at sea weigh from 6.75–25 kg. These powerfully built fish have a dark back with a greenish blue sheen while feeding in salt water. As they approach fresh water to spawn, their colour darkens and a reddish hue appears around their fins and bellies. Adult spawning males develop enlarged teeth and hooked snouts.

Fraser River Chinook Salmon

Background

In Canada, the Fraser River watershed is the largest producer of chinook salmon. Most Fraser River chinook spawn in the middle and upper regions of the watershed, the most notable exception being the Harrison River population in the lower Fraser. Chinook return to the Fraser throughout the year, with most non-Harrison fish arriving in the lower Fraser from April to September; Harrison fish enter the lower Fraser between September and November.

Fraser River chinook spawn from August to December, and most spawners are three to five years old. Fry emerge the following spring; those that spend one year in fresh water are called "stream type", while those that rear less than one year (typically less than six months) are "ocean type". Harrison fish are unusual in that they are all white-fleshed (most non-Harrison chinook are pink-fleshed) and migrate as recently emerged fry directly to the lower Fraser River and its estuary.

A large number of populations comprise Fraser River chinook. For management purposes, they are divided into four major geographical stock complexes and three timing groups. The geographical stock strata are upper Fraser (those returning to the upper Fraser, upstream of Prince George, including Nechako), middle Fraser (downstream of Prince George but excluding the Thompson), Thompson, and the lower Fraser (usually dominated by fall-returning Harrison-origin fish). The timing groups are categorized into three seasonal runs. The early or spring run migrates through the lower Fraser River before July 15, the summer run migrates through the lower Fraser between July 15 and September 1, and the fall chinook, mostly originating in the Harrison, enter the lower Fraser after September 1. The geographical and timing complexes overlap. For assessment purposes, geographic stock aggregates are grouped according to their timing and life history.

Since the early 1980s, the principal hatcheries enhancing Fraser River chinook have been the Chehalis and Chilliwack (lower Fraser); Eagle, Shuswap Falls, Clearwater, Deadman Creek, and Spius Creek (all Thompson); Quesnel (mid-Fraser); and Stuart/Narcoslie (upper Fraser). In recent years, the Clearwater, Eagle, Quesnel and Stuart facilities have been closed. Some enhancement also occurs at small facilities throughout the watershed. Enhancement is thought to have a relatively small effect on the total number of chinook returning to the Fraser, although the effects on certain watersheds, such as the Nicola, which is enhanced by the Spius Creek Hatchery, and the Chilliwack River, which is enhanced by the Chilliwack Hatchery, can be significant.

Many of our inferences about the status of Fraser River chinook are based on spawner escapement data. Most data are derived from visual surveys, which are generally biased to low counts, although they are considered reasonably precise. Counting fences and mark-recapture projects occur for some systems, although they rarely last long enough to examine time series of escapements.

Included in the upper Fraser complex are approximately 16 populations that spawn in the Fraser River and its tributaries upstream of Prince George, including fish from the McGregor, Nechako, Stuart, and Torpy River systems. In most recent years, mark-recapture estimates have been produced for the Stuart River, area-under-the-curve estimates for the Nechako, and fence counts for the Salmon River (Prince George). In the mid-Fraser complex there are 12 populations downstream of Prince George, including fish from the Chilko, Chilcotin and Quesnel River systems. In both complexes, estimates are generated primarily from aerial data and by dividing the peak count by 0.65. Within the Thompson, chinook spawn in tributaries to the lower Thompson River downstream of Kamloops (Deadman River and Nicola River systems), the North Thompson and six of its tributaries, and the South Thompson plus seven of its tributaries, including the lower and middle Shuswap.

Most escapement estimates are produced by expanding peak visual survey estimates, but counting fences or fishways are utilized in the Eagle, Salmon, Bonaparte and Deadman rivers. The Nicola River is the site of a co-operative enumeration project with the local First Nations. The Harrison River population (lower Fraser) has been consistently enumerated by a mark-recapture project since 1984. Chinook escapements to the Harrison were also estimated from 1951-86 by visual surveys. Unfortunately, these estimates were largely subjective and visual estimates in the latter years were influenced by the ongoing mark-recapture program. Therefore, it has not been possible to adequately reconstruct the Harrison time series prior to 1984.

The Fraser River escapement time series is numerically dominated by the Harrison. Returns to the Harrison have been highly variable and without any overall trend. Non-Harrison stock aggregates increased in numbers beginning in the mid-1980s. Since 1995, escapements of the Thompson aggregate appear to have increased more than upper and mid-Fraser populations, likely due to coho conservation measures and declines in late sockeye fisheries.

An examination of the non-Harrison data separated into the major timing groups is more informative. While all early returning aggregates appeared to increase numerically in the mid-1980s, the increase was largest in the upper Fraser. Early runs to the Thompson have been trending downward in recent years, while early runs to the upper and mid-Fraser, which are highly variable, have been without a pattern.

Summer aggregates also increased numerically in the mid-1980s. Summer runs to the Thompson River have apparently been doing well the last several years, while escapements for other summer stock aggregates have remained relatively unchanged.

Fishery Management

Under the 1985 Pacific Salmon Treaty, Canada and the U.S. committed to halting the decline of chinook escapements. Catch ceilings were established for major chinook fisheries from Alaska to B.C. and various time and area closures were implemented. Since 1994, additional fishery management changes have been made to increase the size of spawning stocks of upper Fraser River and other chinook stocks. These have included reduced catch ceilings for the troll fisheries, and increased minimum size limits and reduced bag limits for the recreational fishery. Since 1997, Canadian ocean fisheries have been significantly reduced to lessen impacts on Thompson basin coho, further altering marine catch distributions and lowering ocean catches of Fraser chinook.

Spring-run Chinook

Recoveries of upper Fraser spring-run chinook were rare considering the numbers of coded-wire tags applied, and these tags were recovered in all recovery strata. However, most tags were from the West Coast of Vancouver Island (WCVI)/Entry area. Early returning chinook to the upper Fraser are rarely available to coastal fisheries during July, but are available to entrance and recreational fisheries in May and June during their return migrations.

Currently there are no coded-wire tag application programs for mid-Fraser spring-run chinook. A total of 504 coded-wire tags were estimated to have been recovered coastwide from earlier tagging. Similar to upper Fraser springs, most recoveries occurred in the WCVI/Entry area, with many of these caught in the Juan de Fuca Strait recreational fishery during June.

A greater proportion of chinook originating in the North and South Thompson rivers were recovered in the north and central recovery areas than occurred for upper and mid-Fraser spring chinook. Freshwater recreational recoveries occurred almost exclusively in the lower Fraser River bar fishery, as there were no terminal sport fisheries targeting these (marked) stocks.

Prior to the closure of many of the outside commercial fisheries, recoveries of Lower Thompson springs occurred in all recovery strata with the exception of Alaska, but were most common in the WCVI/Entry area. Since 1997, the number of recoveries in all fisheries declined, with the exception of the terminal and lower river recreational fisheries. While these sport fisheries recovered almost 70 per cent of all Lower Thompson coded-wire tags during 1997–98, they represented only 87 tagged fish, of which 65 were caught in the terminal recreational fisheries at the mouth of the Nicola River.

Early returning spring-run chinook from the Birkenhead River (upper Harrison system) had a very different marine catch distribution compared to any other Fraser River spring chinook. Most Birkenhead chinook, one of the earliest returning populations to the Fraser, were recovered in Alaskan fisheries. Recoveries inside the Strait of Georgia occurred during early spring recreational fisheries.

Summer-run Chinook

Recoveries of upper Fraser summer-run chinook (mostly Stuart) occurred most frequently in the entry fisheries and off the west coast of Vancouver Island, with the southwest Vancouver Island troll fishery and Juan de Fuca Strait net fisheries being the primary contributors. Few recoveries were reported in recreational fisheries. Recoveries in the Fraser River commercial fishery occurred mostly during sockeye openings.

Recovery information for mid-Fraser summer chinook is available in aggregate for mid-Fraser populations before 1997, and for Quesnel River fish in 1997 and 1998. Prior to 1997, mid-Fraser summer chinook were often recovered in entrance net fisheries, although recently most recoveries occurred in northern and Alaskan fisheries and in directed sockeye fisheries in the Fraser. Alaskan recoveries occurred primarily in troll fisheries. Very few recoveries were reported in the Strait of Georgia fisheries or in freshwater recreational fisheries.

No coded-wire tags from North Thompson basin summer chinook have been recovered since 1996. Up to and including 1996, there were an estimated 3,400 recoveries of tagged North Thompson chinook from the Raft, Clearwater and North Thompson rivers. Recoveries were most common in the WCVI/Entry and north-central area fisheries.

South Thompson summer chinook appear to have a more northerly marine catch distribution than other Fraser summer-run populations. A large proportion of South Thompson summer chinook were recovered in the northern waters of B.C. and in Alaskan fisheries. Most freshwater recreational recoveries occurred in the terminal sport fisheries on the lower and mid-Shuswap River.

Fall-run Lower Fraser Chinook

To understand the distribution of Harrison chinook in the marine fisheries, information from chinook salmon tagged and released from the Chehalis River Hatchery was used. (It is not practical to tag adequate numbers of naturally produced juvenile chinook leaving the Harrison River due to their small size.) Since 1981, Harrison chinook have been enhanced at this hatchery, located on a tributary of the lower Harrison River.

Harrison-origin (Chehalis) chinook salmon were predominantly coastal in their marine distribution. Most recoveries have occurred in southern fisheries taking place in WCVI/Entry area, the Strait of Georgia and Washington waters.

Outlook

Forecasts of the next year's escapement for wild-spawning Harrison River chinook are made annually, and a forecast methodology for Harrison-origin chinook spawning in the Chilliwack River is under development. As part of the mark-recapture escapement estimation program at the Harrison, estimates of spawner escapements are partitioned by age class. "Sibling regression" uses the numbers of younger spawners in one year to predict the numbers of older spawners in subsequent years. This method requires that fishery exploitation rates remain constant over time. The method has worked well in most years, but underestimated the returns in 1998 and 1999, when exploitation rates were much lower than average.

The longer term prognosis for fall-returning white chinook is uncertain. Escapements of enhanced Harrison-origin fish to the Chilliwack River have generally increased since the population was established, and in 1995 and 1997 they were estimated to exceed the numbers of naturally spawning chinook in the Harrison. Within the Harrison River, all chinook spawn in a 16.5-km stretch of river downstream from Harrison Lake. The fry migrate downstream shortly after emergence and use side channels and sloughs of the lower Fraser River and its estuary as their predominant rearing locations. The Harrison River is used for log transport and storage, and the lower Fraser River and estuary is affected in numerous ways by the city of Vancouver. The wild population is clearly vulnerable to degradation of these important habitats.

Quantitative forecasts are not made for spring and summer timed stock aggregates. To provide forecasts, better annual sampling for age structures, more quantitative estimates of spawning escapements, and improved in-river catch information separated by population and age are required. For spring populations, recent spawning escapements have been generally higher than during the 1970s, but the trend in the aggregate escapement index in recent years has been downward. Researchers are concerned about the status of this group, especially the earliest components of the run, including the Spius Creek, Coldwater River, Birkenhead River and Upper Chilcotin River populations. Escapements of the summer stock aggregate have generally been higher in recent years, although there has been significant variability among streams. Escapements of upper and mid-Fraser summer stock aggregates have often been weak in recent years, while returns of late South Thompson populations are strong.

It is clear that upriver chinook populations have benefited from reductions in ocean harvests. Canadian marine fishery exploitations were significantly reduced in 1985 in accordance with the rebuilding programme under the Pacific Salmon Treaty and all stock aggregates appeared to increase. Recent fishery reductions, designed in part to conserve upriver populations of Fraser coho and sockeye, have also benefited many Fraser chinook populations, especially summer runs of chinook in the Thompson. In-river harvests of early-run chinook may have delayed their rebuilding.

The long-term prognosis of upriver stocks of Fraser River chinook is uncertain. It is not clear whether the freshwater carrying capacity for these populations has been achieved. Freshwater habitat degradation is a concern in some watersheds. Meanwhile, interim escapement goals, established for all major Fraser chinook stock aggregates about 15 years ago, are currently being reviewed. Many upriver populations are well above these goals, which may have been too conservative, while the Harrison River population has never reached its target. A variety of habitat-based as well as stock-recruit approaches are being used to establish new target escapements.

West Coast Vancouver Island Chinook Salmon

Background

Chinook salmon from the west coast of Vancouver Island (WCVI) are one of the most important natural resources on Canada's west coast. These stocks have long been major contributors to First Nations, commercial troll and sport catches from Alaska to southern Vancouver Island.

WCVI chinook salmon originate in most of the medium and large rivers along the west coast of the island. Spawning escapement records indicate chinook observations in more than 100 WCVI rivers and streams, with 60 of those having records of at least 100 chinook. Of these 60 waterways, 20 have been supplemented through enhancement activities, while 40 support completely wild populations.

Spawning escapements from river systems range from less than 100 to more than 100,000 chinook. In 1992, total escapement to river systems on the West Coast of Vancouver Island reached a record of more than 180,000 chinook. The average reported total escapement between 1985 and 1992 was more than 100,000 fish; 1998's escapement totalled about 120,000 fish.

Most of the larger populations can depend on some form of enhancement to complement natural spawning. Enhancement facilities include small, volunteer projects such as those on the Marble, Zeballos, Tahsis, Leiner, Gold, Burman, Tranquil and Cypre rivers. Other federally-funded community development projects exist on the Marble, San Juan, and Kennedy rivers, and at Thornton Creek. In addition, there are three major hatcheries located on the Stamp, Nitinat and Conuma rivers. These major facilities have also enhanced chinook populations in surrounding systems, such as the Sarita, Nahmint, Tlupana and Toquart rivers, and, through close proximity and straying, in systems such as Canton Creek and Sucwoa River near the Conuma River.

Sexually maturing WCVI chinook migrate to their streams of origin in late summer and fall. The peak of migration into the terminal WCVI areas is usually late August. However, a few populations, such as the Conuma River stock, run about three weeks earlier. Spawning peaks in late September to mid-October. Timing of peak spawn varies by as much as a week or two depending on water conditions and the migration rate into the river.

Emergence from the spawning gravel occurs early in spring of the following year, and within one to three months these ocean-type chinook fry migrate to the ocean. Very few stream-type chinook live in the region. Surveys in the Barkley Sound area suggest that the young-of-the-year chinook may reside in near-shore waters until August before beginning a northerly migration. This early marine phase is critical to the survival of the cohort, and depends on ocean conditions, predation and food abundance.

WCVI chinook migrate northward into northern B.C. and southeastern Alaska waters to rear for two to seven years. As they become sexually mature they migrate south to their natal rivers and streams. On average, 2 or 3 per cent mature and head south at age two, another 15 per cent mature at age three, 55 per cent at age four, and 25 per cent at age five. Less than 2 per cent are left to mature at age six. Male chinook generally mature earlier than female chinook. Typically, none of the mature two-year-old chinook are female, while only 5 per cent of mature three-year-olds are female. Fifty per cent of mature four-year-olds are female, as are about 75 per cent of mature five-year-olds. It is important to ensure that enough larger chinook are conserved to spawn.

Fishery Management

Chinook salmon may be harvested in fisheries from Alaska to the rivers on the west coast of Vancouver Island. Northern fisheries harvest WCVI chinook stocks as both immature fish feeding in the area and as mature adults during their return migration to streams of origin; southern fisheries harvest only maturing chinook en route to their streams of origin. The far northerly distribution of WCVI chinook limits Canada's ability to conserve WCVI chinook, as a large proportion of the catch is in Alaskan fisheries.

Large returns of WCVI chinook in the 1980s and early 1990s resulted in rapid growth of aboriginal, recreational, and commercial fisheries along the west coast of Vancouver Island. The peak fishing period was August through September for local stocks, when they comprised between 90 and 100 per cent of the catch of these fisheries.

Conservation of WCVI chinook stocks in ocean fisheries is accomplished by using the Stamp River/Robertson Creek Hatchery stock (also called the Somass stock) as an indicator. First, a minimum escapement level is established to provide a safe level of natural spawners in WCVI rivers, based on achieving the following level in the Stamp River. Due to variation in age composition and sex ratio between years, the minimum value has been based on:

- 50 million eggs for natural spawning in the Stamp River
- 9.3 million eggs for Robertson Creek Hatchery
- a 1:1 sex ratio for spawning guidelines within the hatchery
- an expected 20 per cent pre-spawning mortality.

Outlook

The average survival rate for WCVI chinook, from release to age two, has been 5–6 per cent. The predicted survival rate for the cohort from the 1995 brood is predicted to be only 0.3 per cent, based on an extremely poor return of three-year-old chinook (from the 1995 brood year). The accuracy of this prediction is high, generally within 10 per cent once three-year-old fish are seen in the terminal returns. The seriousness of the problem is apparent when comparing the predicted 0.3 per cent survival rate to that of other poor years, when ocean conditions were affected by El Niño events. These include the 1 per cent survival of the 1991 brood followed by 0.01 per cent of the 1992 brood, and 0.1 per cent of the 1983 brood. While the problem is apparent,

Distribution of the total fishing mortality of chinook by fishing area, average 1985 to 1994.

Alaskan commercial troll, net and recreational fisheries	37 %
Northern B.C. commercial ocean troll fishery	18 %
Northern B.C. commercial ocean net fisheries	3 %
Northern B.C. ocean recreational fisheries	2 %
WCVI commercial ocean troll fishery	6 %
WCVI recreational fisheries	25 %
Terminal aboriginal fishery, commercial net fishery	7.5 %

the cause is not. These were fish that went to sea in the spring of 1996, and by late 1996 to early 1997, they were in northern waters. Somewhere along the way there was significant mortality, although there was no evidence of large predator numbers.The problem of poor returns appears to be widespread along the west coast of the island. There was corroboration of the poor return of three-year-old chinook to all locations where samples were taken, including the Nitinat, Sarita, Nahmint, Conuma and Marble rivers.

North Coast Chinook Salmon

Background

Chinook salmon stocks along the north coast (Areas 1–6) are classified primarily as stream-type, though both ocean- and stream-type fish are present in most populations in varying proportions. The largest number of chinook stocks occur in the Skeena River and its tributaries (Area 4), with significant numbers also occurring in tributaries of the Nass River (Area 3). The Yakoun River supports the only major stock in the Queen Charlotte Islands (Area 1), while the Kitimat River (Area 6) supports the only other major chinook stock along the north coast. The most information available on the status of north coast chinook comes from tributary stocks of the Skeena River, in particular the Kitsumkalum River summer run.

The status of north coast chinook is evaluated primarily by observed escapement to individual streams. Skeena stocks are also monitored in-season by the Tyee test fishery. The most extensive and complete records available on north coast escapement are for Area 4 (primarily Skeena River) stocks, with records extending back to 1950. With the exception of 1959, escapement of Skeena chinook salmon generally varied between 20,000 and 60,000 during the 1950s. The large escapement in 1959 was primarily due to an exceptionally large escapement to the Bear River. A combination of increased fishing pressure, poor brood survival and low water conditions contributed to lower escapements from the early 1960s through the early 1980s.

Changes to the commercial fishery through implementation of the Pacific Salmon Treaty in 1984 were no doubt responsible in large part for a dramatic increase in Area 4 escapement in the years immediately following. Escapement more than doubled after 1983 from 20,000 to more than 50,000 fish for the remainder of the 1980s and early 1990s. Since then, with the exception of 1995 and 1996, Area 4 escapement has remained between 40,000 and 70,000 fish. However, while total escapement has remained moderately high, some stocks, such as the Kitsumkalum, have suffered low escapements during much of the last decade.

Fishery Management

North coast chinook (Areas 1 – 6) are harvested in a number of commercial, sport and aboriginal fisheries in both Alaska and Canada. Annual commercial catch increased from about 150,000 fish in the early 1960s, to between 200,000 and 300,000 fish through the 1970s and 1980s. This harvest level was maintained up until 1992. Since then, landings have declined to less than 200,000 fish, due in part to restrictions placed on commercial salmon fisheries during the mid- to late 1990s.

In Alaska, the commercial net, tidal sport and particularly the commercial troll fisheries harvest a sizable proportion of north coast chinook. In Canada, the northern net and northern troll fisheries have traditionally been the most important commercial harvesters of these stocks, with tidal and freshwater sport fisheries also accounting for a portion of the annual harvest. Aboriginal food fisheries also harvest north coast chinook, particularly in the Nass and Skeena watersheds.

The most extensive information available on north coast chinook exploitation comes from the Kitsumkalum summer run, which has been monitored since 1984 as an exploitation indicator for north coast stocks. Data analyses indicate that this stock was heavily exploited during the 1980s and 1990s. Tag returns show that until 1998, Alaskan fisheries accounted for between 30 and 57 per cent of all fishing-related mortality, most of which occurred in the commercial troll fishery. In Canada, northern troll and net fisheries have, until recently, accounted for the majority of Canadian catch mortality. However, restrictions on commercial salmon fisheries in Canadian waters in 1997–98 virtually eliminated Canadian commercial harvest of Kitsumkalum chinook. By 1998, the Alaskan proportion of the harvest had reached 79 per cent. Limited tag returns for other north coast stocks suggest that they are harvested in a similar pattern. However, some stocks which return to fresh water earlier than the Kitsumkalum run, such as the Cedar and Upper Bulkley, are more lightly exploited.

Outlook

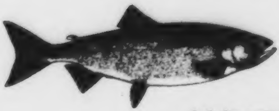
Unlike a number of chinook salmon runs in southern B.C., north coast chinook, on the whole, appear to be healthy. Even though information from the Kitsumkalum stock indicates that north coast chinook have been heavily exploited since at least the early 1980s, spawning escapements to most major north coast systems have remained relatively strong throughout this period.

The restrictions on the commercial salmon fishery in 1998 aimed at protecting endangered coho stocks resulted in a significant increase in escapement of chinook to a number of systems that year. The Kitimat River was the only major stock to show a significant decline. With the continued restrictions on Canadian commercial fisheries in 1999, as well as the recently signed second Pacific Salmon Treaty, escapements of north coast chinook should continue to improve, at least in the short term.

CHUM SALMON

Chum salmon (*Oncorhynchus keta*) have the most extensive geographic distribution of all the salmon species. In North America, they are found in the coastal streams of northern California, Oregon, Washington, B.C. and Alaska (including the Aleutian Islands), as well as the Yukon and Mackenzie rivers in the Arctic.

Chum fry migrate to the ocean shortly after emerging from the gravel but spend time rearing in estuaries before migrating to offshore feeding grounds in the Northeastern Pacific Ocean. When they move to their feeding grounds, chum originating in B.C. occupy a wide area of the Gulf of Alaska, mingling extensively with northern gulf stocks and, to a lesser degree, with fish from western Alaska and the Yukon.



Adults return along coastal routes to their natal rivers to spawn after two to seven years at sea, with ages three to five predominating. In B.C., chum spawn in more than 880 moderate-sized streams, and are the latest of the five salmon species to enter southern streams and rivers.

While some have been know to weigh 15 kg, chum salmon average 3.5–4.5 kg and can measure more than 100 cm at maturity. They are attractive fish, metallic blue and silver in salt water, with occasional black speckling on the back. As they near fresh water on the return to their natal streams, their flesh quality and visual appearance deteriorate rapidly. Mature chum show reddish or dark bars across the sides, and some display blotches of grey or black. The males also develop a sharply hooked nose and dog-like teeth (hence the common name "dog salmon").

Because their flesh is pale and low in fat content, chum salmon are usually marketed fresh, frozen or smoked.

Inner South Coast Chum Salmon

Background

More than 400 populations of chum salmon originate from the Inner South Coast of B.C., in Johnstone Strait, Strait of Georgia and Fraser River watersheds. Forty-five of these populations are responsible for 85 per cent of total production in this area, with Fraser River stocks being the largest producers. Chum returning to spawn in their natal streams in these three watersheds migrate primarily through Johnstone Strait. Because of their overlapping timing and migration route, they are grouped into a single unit commonly known as the Inner South Coast chum stock.

Inner South Coast chum are divided into two groups based on run timing – summer run and fall run. Summer chum migrate from June to August, spawning in September and early October; fall chum migrate from September to November, spawning from

October to January. Only fall stocks are actively managed in mixed stock fisheries. Summer stocks are managed in terminal areas where local surpluses are harvested, with the major inside summer run stocks occurring in Bute and Knight inlets.

Fishery Management

Chum did not assume commercial importance in B.C. until the First World War. Catch statistics for the 31-year period between 1917 and 1947 show an increase in chum catches coincident with declining sockeye catches resulting from the 1914 rock slide that blocked fish passage at Hell's Gate on the Fraser River. Declines in chum abundance were recorded in the early 1940s and it seems highly probable that total returns were low in the early 1920s and 1930s. From 1939 to the early 1950s, chum salmon catches steadily increased. However, they were reduced to low levels from the mid-1950s through the 1960s, primarily due to high exploitation rates. To address this problem exploitation rates were drastically reduced in the 1960s. Major enhancement efforts were initiated in 1980, with the "Clockwork" management plan implemented in 1983. In 1985–94, total returns increased, but in 1995–97 they were less than average.

Fall chum salmon migrating to their spawning grounds through Johnstone Strait and the Strait of Georgia encounter several fisheries, beginning with the 110-km long Johnstone Strait fishery in Areas 12 and 13. Here chum are concentrated during their inshore migration and are subjected to seine, gill net and troll fisheries. The catch in this fishery has averaged about 68 per cent of the total Inner South Coast commercial catch, or 800,000 chum annually in 1990–98.

The terminal fall chum fishery at Qualicum Bay harvests predominately enhanced chum stocks from the Big Qualicum, Little Qualicum and Puntledge River hatcheries. The catch in the Qualicum fishery averaged 240,000 chum annually in 1990–98. Cowichan, Goldstream, Nanaimo and Nimpkish rivers, as well as Jervis and Bute inlets also have terminal fall chum fisheries, which target mainly local stocks. The Fraser River fishery (Area 29) includes the 80 km of the Fraser River downstream from Mission, the estuary and the adjacent waters of the southern portion of Georgia Strait. The Fraser River fishery harvests predominately enhanced chum salmon from the Harrison, Chehalis, Inch, Stave and Chilliwack/Vedder systems. Canadian chum, primarily of Fraser River origin, are also harvested in U.S. fishing areas.

Chum salmon are important to many First Nations people for food, ceremonial and social purposes. In the late 1800s and early 1900s, commercial fishers considered chum less desirable than other salmon species. In the early 1990s, Fisheries and Oceans Canada offered First Nations greater access to the salmon resource through the Aboriginal Fisheries Strategy. This initiative resulted in greater participation by First Nations in Inner South Coast chum fisheries.

Inner South Coast chum stock assessments are based on catch data from test, commercial and First Nations fisheries, biological samples for age composition and genetic stock identification, mark-recovery program fin clips, and escapement estimates from wild and enhanced systems. Catch of Inner South Coast chum stocks declined sharply between the early 1950s and the mid-1960s, with escapements remaining low but stable during this period. The rapid decline in stock size in the early

1960s prompted the complete closure of commercial chum fisheries in 1965–66. The stock recovered, and by 1973 the chum catch reached nearly 3 million, with an escapement of nearly 2 million.

The exploitation rate on Inner South Coast chum generally exceeded 50 per cent in the 1950s, but declined in the 1960s as the stock size declined. From 1975–83, exploitation rates were less than 20 per cent in odd years, but topped 40 per cent in even years. More recently, the exploitation rate has averaged 37 per cent (1983–93). Increases in total Inner South Coast chum stock after 1985 resulted partially from the development of major enhancement facilities and comprehensive management plans.

Major enhancement projects for Inner South Coast chum started in 1980. There are now seven major facilities – three on Vancouver Island, at Big Qualicum, Little Qualicum and Puntledge hatcheries, and four in the Fraser River, at Chilliwack, Inch Creek, Stave and Chehalis hatcheries. Major returns of enhanced chum from these facilities were first recorded in 1985. In addition, numerous small facilities and habitat restoration projects are operating within the Inner South Coast management area. Enhancement may be an important strategy for both rebuilding chum stocks in the short term and providing consistent terminal fishing opportunities in the long term. The production potential for major facilities throughout the Inner South Coast is 1.3 million chum at favourable marine survival rates.

Clockwork Management

The Johnstone Strait Clockwork Management Strategy was first implemented in 1983. The plan's main goal was to rebuild Inner South Coast wild chum stocks within 12 to 15 years to a target escapement level of 2.5 million chum (including 700,000 Fraser River chum) by controlling the overall harvest rate. The Clockwork strategy also stipulates limited fishing at low abundance levels, thereby stabilizing the annual catch. Incremental harvest rates for marine fisheries are set at 10, 20, 30 or 40 per cent, depending on the run size. A pre-season forecast of abundance is used to determine the expected rate, which is adjusted with in-season information from test and commercial fisheries. The Clockwork plan allows both catch and escapement to increase with increasing total run size up to a maximum harvest of 40 per cent.

A Fraser River Clockwork plan was introduced in 1987 to provide management goals and fishing limits for the harvest of Fraser River chum, independent of the Johnstone Strait fishery. Under these two Clockwork management plans, the overall exploitation rate on Inner South Coast chum stocks averaged 41 per cent (ranging from 17 to 51 per cent) during the 1990–97 period. Since the initiation of the Clockwork strategy in 1983 and increased enhanced production from 1985 onwards, overall returns have increased. The average total wild production in 1968–82 was 2.1 million, compared with 2.4 million in 1983–97.

All of the increase in Inner South Coast chum production is due to the Fraser River component. The average return in Fraser River chum salmon rose from 800,000 in 1968–82 to 1.3 million in 1983–96, an increase of 63 per cent. In contrast, there was a slight decrease for the Inner South Coast non-Fraser wild chum of 15 per cent. The average return for this group was 1.3 million fish in 1968–82 and 1.1 million in

1983–96.

Outlook

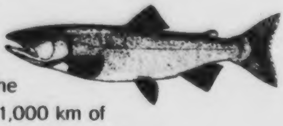
Since total returns during 1995–97 were less than average, they suggest that Inner South Coast chum stocks suffered from lower than expected marine survival rates. The declines in survival could be related to changes in the marine ecosystem caused by the general warming of the Northeastern Pacific Ocean in recent years. Some increased catch and escapement estimates, however, suggest that marine survival rates may have improved for chum salmon.

Accurate pre-season forecasts of chum returns require determining sources of variation in survival rates and the effects of fluctuating environments on survival, particularly rainfall, freshwater temperatures and oceanic conditions. Forecasting is further complicated by varying age at maturity in chum salmon and difficulty in estimating the size of escapements. Factors such as intraspecific and interspecific competition may also affect juvenile size, age at maturity and marine survival.

COHO SALMON

Coho salmon (*Oncorhynchus kisutch*) originate in streams around the North Pacific Ocean, from California and the Sea of Japan north to the Bering Strait. They are swift, active fish, a favourite of the saltwater sport fishery. Next to pinks, they probably have the most consistent life history of west coast salmon.

Juveniles are aggressive, territorial and often vibrantly coloured, with a large orange anal fin edged in black and white. They may be difficult to distinguish from chinook, with which they co-occur. In fresh water, coho feed on aquatic and aerial insects, plankton and occasionally small fish.



Migrating to sea in the spring, some male coho (jacks) will mature and return to their birthplace to spawn in the fall of the same year. The rest continue to grow rapidly, usually within 1,000 km of their home stream. In the ocean, coho feed at first on euphausiids and other plankton, and later on squid, herring, sand-lance and small fish. They return the following summer and fall to spawn in their natal streams, primarily from October to December.

As adults, coho have silvery sides and metallic blue backs with irregular black spots. Spawning males in fresh water may exhibit bright red on their sides, bright green on their backs and heads, and darker colouration on their bellies, as well as marked hooked jaws with sharp teeth.

Coho salmon remain in surface waters near the coast throughout their lives in the ocean, and are readily caught with hook-and-line gear. Prior to 1900, coho were caught using hand lines from rowboats or dugout canoes. Around 1910, powered boats were introduced and commercial trolling, as it is now known, began. Coho are now harvested in directed hook-and-line commercial and recreational fisheries throughout their second year in the ocean.

The 1920s saw the advent of gill net and purse seine fisheries directed at intercepting coho. Although there are currently no directed net fisheries for coho, a substantial bycatch occurs in gill net and seine fisheries for sockeye, pink and chum salmon. Unlike sockeye, pink and chum salmon – but like chinook – most coho are harvested in rearing areas, not during their spawning migrations. As a result, coho fisheries catch individuals from potentially hundreds of populations. Coho are also harvested in "gauntlet" and "terminal" fisheries directed at other salmon species, such as sockeye, as they return from the high seas to their natal streams. A typical coho fishery is thus a mixed-stock fishery, which poses many problems for the assessment and management of the species.

Georgia Basin Coho Salmon

Background

In more than 350 streams around the Strait of Georgia, including the Lower Fraser River drainage as far upstream as Hope, young coho rear for one and sometimes two years. Juvenile coho prefer low-gradient habitats with low water velocities and an abundance of cover, and are numerous in streams, lakes, and beaver ponds throughout the Georgia Basin. They also occur in marginal sloughs of large rivers.

The conservation of Georgia Basin coho has been an issue since at least 1989, when the Pacific Scientific Advice Review Committee (PSARC) first identified a need to reduce total fishery exploitation rates. Spawning escapements to most south coast B.C. streams showed improvements in 1997 over the extremely poor runs of 1996. Spawning numbers generally increased again in 1998 in response to the much reduced exploitation, more so in the northern strait than further south, where the response was more sluggish (southeastern Vancouver Island) or inconsistent (Lower Fraser River).

The reduced abundance of coho in recent years is due in large part to much reduced marine survival rates observed for most hatchery and wild stocks. Survival rates of 8–18 per cent in the 1980s have declined to 1 per cent or less in many of these stocks. Near-zero exploitation rates will need to be maintained to stabilize escapements under these poor ocean conditions and permit future rebuilding.

The other major concern in the decline of coho is the loss and degradation of freshwater habitat due to increasing economic and development pressures in the Strait of Georgia. The loss of habitat is associated not only with the increased numbers of people living in the area but also with the ever-increasing intensity of resource use. Low-gradient streams within 100 km of the coast make up a significant proportion of the freshwater habitat for coho in B. C. These are the same areas where logging, agriculture and urbanization have resulted in stream degradation. Coho habitat, especially in small streams, remains threatened in the Lower Fraser Valley, along the Sunshine Coast, and on Vancouver Island from Sooke to Campbell River.

Fisheries and Oceans Canada has a number of initiatives to involve communities in the protection of streams and wetlands. This will be critical for the identification, protection and rehabilitation of coho habitat in the south coast area.

Fishery Management

Strait of Georgia coho are caught in aboriginal, recreational, and commercial net and troll fisheries. Coho catches on the south coast of B.C. have declined since the mid-1980s, initially due to declining abundance and more recently because of severe conservation measures. Total fishery exploitation rates were reduced from a range of 75–80 per cent to a range of 65–70 per cent. However, declining marine survival rates over the last decade have reduced stock productivity to the point where PSARC judged even this lower target range to be too high. Fishery management achieved its reduced target of 60 per cent exploitation in 1995 and 1996, then lowered it further to about 37 per cent in 1997 and only 5 per cent in 1998.

The catch was 1.55 million in 1995 and is now virtually zero. Strait of Georgia stocks comprise a significant portion of these catches, with the remainder originating on the west coast of Vancouver Island, in the United States and the Upper Fraser River drainage.

In addition to declining catches, coho harvest distribution has changed. In six of the past eight years (1991 and 1994–98) unusually high proportions of the Strait of Georgia coho catch have been taken off the west coast of Vancouver Island rather than in the strait itself.

While the aboriginal harvest of coho is small compared with other salmon species, several First Nations rely partly on coho for food, social and ceremonial purposes. Coho are caught in hook and line, net and spear fisheries in or near their local streams. They are also caught incidentally by other salmon fisheries.

Eighty-nine per cent of the commercial coho catch on the south coast of B.C. was taken by troll fleets and the remainder by net fisheries. The west coast of Vancouver Island (WCVI) troll fishery is the single largest commercial harvester, taking an average of 1.51 million coho in the 10-year period before 1997, when major restrictions were imposed. This fishery was controlled by a Pacific Salmon Treaty catch ceiling, which limited the catch for many years. Coho caught in this fishery are bound for U.S., Strait of Georgia and WCVI spawning grounds. The troll fishery inside the Strait of Georgia has not been permitted to retain coho since 1995. Although its catch was historically much smaller than the WCVI troll fishery, it was made up of a very high proportion of Strait of Georgia stock.

Net fisheries in Johnstone Strait, Strait of Juan de Fuca and the Strait of Georgia harvest coho incidentally during directed fisheries on sockeye, pink and chum salmon. Strait of Georgia coho are predominant in the Johnstone Strait and Strait of Georgia net fisheries, while coho originating in the U.S. are the main stocks in the Juan de Fuca net fishery. Curtailment of net fisheries in recent years due to low returns of the target species and concerns for chinook and coho have resulted in reduced coho catches in net fisheries.

Recreational fishing in B.C. tidal waters is important to many residents and visitors. Until the recent distribution shift and severe fishing restrictions occurred, about 70 per cent of tidal recreational fishing took place within the Strait of Georgia. Chinook and coho are the primary species of this fishery, largely because they remain in nearshore waters longer than sockeye, which are available to anglers only for a short time during their spawning migration back from the high seas. While chinook are the glamour fish, coho have been the mainstay of the recreational fishery in the Strait of Georgia because they have been more abundant than chinook and are generally easier to catch.

During "inside" years, when coho are abundant in the Strait of Georgia, the recreational fishery is a significant harvester of Georgia Basin stocks. During "outside" years, when coho migrate to the west coast of Vancouver Island, the impact of the recreational fishery is reduced. From 1988–97, excluding 1994, which was an intermediate year for catch distribution, the average catch in the Strait of Georgia recreational fishery in inside years (1988–90 and 1992–93) was 750,000 coho. In outside years (1991 and 1995–97) it was 160,000. Overall, including 1994, the average catch was 470,000 fish. Up to 1996, the average catch of Georgia Basin coho elsewhere on the south coast was estimated to be 60,000.

Since 1995, most coho normally resident in the Strait of Georgia have migrated to the west coast of Vancouver Island. Consequently, very low numbers of coho have been available in the Strait of Georgia and fishery efforts there have also declined to a very low level.

Outlook

Conservation concerns for Georgia Basin coho have been expressed by Fisheries and Oceans Canada since the late 1980s. High fishery exploitation rates, steadily declining numbers of coho surviving at sea, and habitat degradation are the primary factors contributing to the reduction of spawning escapements.

Scientists studying changes in climate and fish stocks, both in the Strait of Georgia and globally, have different views on the long-term outlook for coho. Some believe that a "regime shift" or change in the ecosystem of the Strait of Georgia is occurring, while others believe that current conditions are part of a longer term cycle that will eventually see a return to the cooler conditions that typified the middle decades of this century. Regardless of these differences over the long term, consensus is that the short-term outlook for coho is not bright.

Fishing mortality must be virtually eliminated to maintain generally adequate spawning levels during this period of extremely poor marine survival. Harvest management needs to be risk-averse – when managers are uncertain, they must err on the side of caution. Uncertainties in the migration pattern of Georgia Basin coho will demand that harvest management actions encompass not only the Strait of Georgia but also the approach routes of Johnstone Strait and Strait of Juan de Fuca, as well as the west coast of Vancouver Island, with the importance of each area varying from year to year.

Upper Fraser/Thompson River Coho Salmon

Background

Upper Fraser/Thompson River coho originate in four sub-regions: the Upper Fraser, North Thompson, Lower Thompson and South Thompson. As a group, they are descended from coho of the upper Columbia River and are genetically distinct from coho in the Lower Fraser River. Recent spawning escapements (1996–98) in the North and South Thompson drainages are less than 30 per cent of the average escapements during 1988–95. The main reasons for the decline are reduced marine survival and fishery exploitation rates exceeding those that the stocks can withstand.

In response to conservation concerns for Thompson coho, severe restrictions were placed on B.C. salmon fisheries in 1998, resulting in a lowering of the overall exploitation rate to about 7 per cent (2 per cent in Canada). However, while there was a slight improvement in 1998 over 1997, for most unenhanced streams returns in 1998 were less than in 1995, their brood year. Overall, the status of South and North Thompson coho remains poor. Their productivity has declined in the last 10 years to the point where many populations are not replacing themselves, even with major reductions in fishing impacts.

Many inferences about the status of Thompson River and other Upper Fraser River coho stocks rely upon spawner escapement data. The coho salmon escapement database for Thompson basin stocks was filtered to remove the confounding effects of inconsistent monitoring and enhancement. Spawning escapements to unenhanced streams in the North and South Thompson were at moderate levels from 1975 through the early 1980s. For the next five or six years returns were higher, but subsequently declined until 1996. Escapements to each aggregate increased annually from 1996–98. Although time series of escapement data for Lower Thompson and Upper Fraser/non-Thompson rivers are of shorter duration and lower quality than those for the North and South Thompson, the status of these stock aggregates appears better than the North and South Thompson.

While a small increase occurred in the total number of coho returning in 1998 compared with 1997, spawning in the North and South Thompson drainages continues to be concentrated in relatively few streams. Thirty-two per cent of streams that had fish observed in them in 1988 had reached "none-observed" status in 1997, which is three generations later. This proportion remained largely unchanged for 1998 spawning relative to 1989 distribution (27 per cent).

A great deal of uncertainty surrounds the precision of these proportions, as reporting methods for the data have varied considerably. Nevertheless, even with increased effort to find fish in 1998 and the near absence of fishing in B.C., many streams were devoid of spawners. Thompson River coho returns did not improve in 1999 or 2000, likely due to poor marine survival, and are expected to remain low in 2001. Continued conservation measures will continue to ensure impacts on this stock are minimized.

Fishery Management

Coded-wire tags from Thompson and other Upper Fraser River coho have been recovered in fisheries from Alaska to Oregon. Most were gathered during troll and recreational fisheries off the west coast of Vancouver Island and in the Strait of Georgia. Upper Fraser/Thompson coho have also been caught incidentally in net fisheries for other species in Johnstone Strait, Strait of Juan de Fuca, Strait of Georgia, the San Juan Islands and the Fraser River. Their recent catch distribution has been dominated by dramatic swings between fisheries inside and outside the Strait of Georgia. Prior to 1991, large numbers of coho remained inside the Strait of Georgia each year and supported major recreational and trawl fisheries. In 1991, and from 1995–98, the majority of coho appeared to leave the strait. Marine fishery exploitation rates (catch as a proportion of catch plus escapement) averaged approximately 65 per cent during 1987–97, and were about 8 per cent in 1998.

Recreational fisheries for coho salmon in the Upper Fraser River and tributaries have been limited and often focused on enhanced stocks. Upper Fraser/Thompson coho are also angled in the Lower Fraser River, but harvests are minor.

From the mid-1970s to present there has been limited effort in the Fraser River watershed by First Nations directed at coho salmon. The preferred species based on catch and effort are sockeye and chinook. Most aboriginal harvests of coho in recent years occurred at enumeration fences on enhanced stocks.

Canadian salmon have seen unprecedented restrictions since 1997, and especially in 1998. In 1998, no directed fisheries on wild stocks of coho were permitted, and mandatory non-retention and non-possession of incidentally caught coho was implemented in all areas, with the exception of some terminal hatchery locations. The coast of B.C. was divided into a series of red and yellow zones. In the south, red zones consisted of those areas and times where Thompson coho stocks were expected to be prevalent. Yellow zones were areas where Thompson coho were not expected to be prevalent. Prevalence was determined by the historical frequency that coho of known Thompson origin were captured, as determined by analyzing coded-wire tag data.

Only a small number of restricted experimental and test fisheries were allowed in red zones in 1998, and these were closely monitored. In yellow zones, the only salmon fisheries permitted were directed on species other than coho. To reduce the bycatch and mortality of coho in yellow zones, a selective fishing strategy was implemented for all commercial gear types. Logbooks were mandatory and an onboard observer program was instituted in southern B.C. Also, recreational fisheries were monitored more intensively than in previous years.

Tissue samples were collected from coho in many fisheries in 1998 to estimate the proportion of Thompson-origin fish. Stock compositions were estimated from DNA analysis and the historical distribution of coded-wire tags. The numbers of Thompson coho estimated to have been killed in southern B.C., northern B.C. and U.S. fisheries were 205, 105 and 953, respectively. Almost all of the U.S. mortalities occurred in Washington.

Fisheries and Oceans Canada has built on the knowledge and experience gained since 1998 and, in doing so, has implemented a more flexible approach to management of these stocks. This has permitted fisheries where there were none, while still protecting depressed stocks.

Outlook

The extreme management measures undertaken in B.C. during 1998 to conserve coho appear to have stemmed the decline for some populations. Numbers of coho in the Upper Fraser/Thompson may be larger than previously thought, but those streams with very few fish in them continue to be at risk of local stock extinction.

The short-term forecast for Thompson coho is for continued lower-than-average returns, in part because marine survival rates are expected to remain low. The 1996 and 1997 spawning populations were small, and concern exists that the reproductive potential of these broods may be lowered because of male-biased sex ratios and reductions in fecundity. Low parent spawner abundance and poor prospects for the return per spawner rate mean that no significant improvements to the overall abundance of Thompson River coho are anticipated for the next two years. To conserve these populations, levels of fishing mortality will continue to be minimized.

West Coast Vancouver Island Coho Salmon

Background

On the west coast of Vancouver Island (WCVI), young coho rear in streams and lakes for one and sometimes two years. Migrating to sea in the spring, some males (jacks) will mature and return to their birthplace to spawn in the fall of the same year. The rest continue to grow rapidly, feeding on a variety of prey, usually within 1,000 km of their home stream. They return the following fall to spawn, and then die.

There may be as many as 700 distinct WCVI coho populations, most of which are located in Areas 24–27. Of the 200 or so populations with reported escapement, half have spawner estimates averaging fewer than 85. Only the Somass (Area 23) and San Juan (Area 20) rivers have more than 5,000 spawners, on average. Through analysis of catch and fishery harvest rate data, the total escapement of wild WCVI coho has been estimated at between 70,000 and 270,000 in the 1988–94 period, with a median escapement of 180,000.

Assessments of WCVI coho populations are based on information from a set of indicator stocks. Carnation Creek, located near Bamfield, is the primary source of information on wild stocks. The best escapement data, other than those from Carnation Creek, come from an annual census of coho on Gold River and fishway counts at Stamp Falls in the Somass River system. The only place where tagging allows measurement of exploitation rate and marine survival is Robertson Creek Hatchery on the Somass River system. Catch distributions are also monitored at Conuma River and Nitinat River hatcheries. Starting in 1995, annual fry and adult salmon surveys have been conducted on 30 to 40 WCVI streams in order to compare abundance in non-indicator systems.

Escapements to Carnation Creek and Gold River have varied but no consistent trend has been observed since monitoring began in 1971. Based on these indicators, the long-term exploitation rate of 65–70 per cent measured at Robertson Creek Hatchery has not been excessive in the last 25 years. There has been a marked decline in marine survival over this period. The low marine survival of Carnation Creek coho and subsequent low escapement levels have been compensated by higher freshwater survivals. This may be a general WCVI phenomenon that has allowed these stocks to remain relatively healthy. Coho escapements for WCVI rivers rose dramatically in 1998, with record high escapements in some cases – double or triple the 1995–97 average escapements.

The marine survival rates of WCVI coho have generally declined to about 40 per cent of what they were 20 years ago. The decline was punctuated by the extremely poor survival rate of the coho that went to sea in 1993 and returned to spawn in 1994.

Fishery Management

The WCVI commercial troll fishery was the largest harvester of coho salmon in B.C., averaging 1.65 million salmon from 1985–94. The fishery has been managed to a catch ceiling under the Pacific Salmon Treaty since 1985: 1.75 million in 1985–86, 1.8 million in 1987–92, 1.7 million in 1993, 1.2 million in 1995, and 1 million in 1996 (there was no ceiling in 1994). The fishery was managed by a statistical strategy that called for area closures or openings if catches during the season exceeded a red-line level or fell below a green-line level.

The median annual catch of WCVI coho populations was estimated to be 464,000 between 1988 and 1994. Three major hatcheries – Nitinat River (Area 22), Robertson Creek (Area 23) and Conuma River (Area 25) – produced about 9.4 per cent of the total. Almost all of the catch was taken in the WCVI region by commercial troll fisheries, with recreational and aboriginal fisheries taking smaller shares.

In 1997, due to conservation concerns, there were no directed coho fisheries. Coho were caught during the WCVI chinook troll fishery, but after one week of fishing, coho encounters reached unacceptable levels and the chinook fishery was terminated as well.

In order to protect depressed coho stocks in 1998, especially those from the upper Skeena and Thompson rivers, two measures were taken – no directed commercial fisheries were allowed on coho salmon, and other fisheries known to intercept coho were subjected to new geographical restrictions. Under the plan, Pacific Region waters were divided into yellow and red zones. Only in the yellow zones, where past coded-wire tag recoveries indicated endangered stocks were not prevalent, was commercial and recreational fishing for other species allowed. These fisheries were required to release any live coho that were caught during operations. No fishing was allowed in red zones, areas in which Thompson River coho were known to be prevalent. Red zones included inshore waters of Victoria to Barkley Sound and offshore waters of Barkley Sound to Quatsino Sound, from June to September. Rules governing fishing in the red and yellow zones were maintained for the 1999 season.

One exception to the non-retention of coho occurred in 1998. A large coho return enabled a recreational fishery to catch coho in the non-tidal portion of the Stamp River during the fall. Catch was highly variable, with good catches of more than 10 fish a day obtained below Stamp Falls in late September and early October. WCVI coho returns remained low in 1999 and 2000 and conservation measures will remain in place through 2001. As in the last three years, there will be no directed fisheries on coho and there will be non-retention of coho by-catch in all fisheries for 2001.

Outlook

Fishing restrictions that began in 1998 have resulted in more coho reaching WCVI rivers to spawn. Although not considered threatened compared with coho in other areas, WCVI coho stocks must be closely monitored during poor marine survival periods to ensure that sufficient numbers reach the spawning grounds. New forecasting methods are under development to predict subsequent adult returns.

Skeena River Coho Salmon

Background

The coho salmon occurs throughout the Skeena River and its tributaries. Approximately 25 major populations of coho and numerous smaller ones reside in the Skeena system. Although the proportions vary over time, about half of Skeena coho migrate north along the Alaska panhandle, with the balance remaining in the coastal waters of northern B.C. There have been occasional recoveries of Skeena coho in the troll fisheries off the west coast of Vancouver Island and in the Strait of Georgia, while the majority are caught in the coastal troll and net fisheries of southern Alaska and northern B.C.

Fishery Management

Increased catches of coho in the Area 4 seine fishery began in the early 1970s, coincidental with increased fishing on enhanced Babine Lake sockeye. The catch in the seine fishery, however, remains small. Before 1980, trends in the northern troll catch and the Area 4 gill net catch of coho were similar and probably reflected the abundance of coho in the Skeena River and other producing systems on the north and central coasts. The Area 4 gill net catch of coho has shown no significant trend over the last 20 years, while the catch in the northern troll has been declining since the peak catches of the mid-1980s.

Because coho are harvested in mixed-stock fisheries, it is not routinely possible to determine the catch for individual populations or groups of populations, even for large aggregates such as the Skeena River stock. Individual populations can be tracked in fisheries if the smolts have been given a coded-wire tag and an external mark.

The coho of the Lachmach River, which is located at the head of Work Channel, is a wild (not enhanced) population used as an indicator for populations on the north coast including the Skeena. The Toboggan Creek (a lower tributary of the Bulkley River) and Babine populations have been enhanced through community development projects of the Salmonid Enhancement Program. The Babine population is reared in net pens on Nilkitkwa Lake near Fort Babine.

The catch distributions of all three populations are highly similar. Compared with the Babine coho, a slightly higher proportion of Lachmach coho are caught in the northern troll fishery and a slightly lower proportion in the northern nets, but the two populations are otherwise similar. Toboggan coho have a slightly more southerly catch distribution compared with the two other populations, and are also caught in significant numbers in a freshwater recreational fishery on the Bulkley River.

Four indices of abundance are used to determine the status of Skeena coho. Three involve measures of escapement – the number of adult coho returning to the Skeena to spawn. Estimates of escapement begin between 1946 and 1956, thus allowing the description of trends over five decades. As the area covered by these indices ranges from Babine Lake to a major part of the watershed, the indices give a coarse measure of abundance.

The first index is a count of coho passing through a fence on the Babine River below Nilkitkwa Lake. The fence has been operated since the fall of 1946 primarily to enumerate sockeye salmon returning to the Babine. Estimates of the total escapement of the Babine Lake coho aggregate have been between 453 to 22,985, a range of more than 50-fold. The decadal median escapement for the 1990s is 21 per cent of the median for the 1960s. The reduction in total stock size over the same period was only slightly less severe (to 26 per cent).

The temporal patterns of the reductions in stock size and escapement are slightly different. A graph of escapement against time is noticeably step-shaped, with a marked drop in escapement occurring in 1979. The time series of total stock size is not stepped and shows a continuous decline since the early 1970s.

Between 1970 and 1998, the size of the Babine Lake coho aggregate shrank by an average of 5 per cent each year. This is termed the finite rate of decrease. The average age of a Babine coho at return is 3.3 years. Consequently, every generation the size of the aggregate shrank by an average of 16 per cent. These rates are modest compared with those seen in the coho of the Thompson River, where generational decreases of 54–72 per cent have been observed since 1988. However, the decline of the Babine aggregate may have been going on for much longer.

The coho escapement in 1998 to Babine Lake was 4,291, a number comparable to that of the early 1990s and nine times the low escapement in 1997. However, the total stock size in 1998 was the fourth lowest on record. Clearly, the increase in escapement was due to the conservation measures taken in Canadian fisheries, not to a recovery of the populations of the Babine. Existing enhancement efforts have been continued on coho stocks for the Upper Bulkley, Kispiox and Babine rivers and Tobaggan Creek. New strategic enhancement efforts were started on other coho stocks from the Upper Bulkley, Morice and Upper Owen Creek and the Morrison River, a tributary to Babine Lake.

The second index is generated from the catch of coho in the Tyee test fishery. The test fishery is primarily intended for in-season management of the Skeena sockeye fisheries, but because coho, chinook, steelhead and pink are also caught, it has been routinely used as an abundance index for all salmon species returning to the Skeena River. The test fishery has operated from July 1 to August 25 in the same location with the same gear since 1956. Most years the test fishery has operated into September. The test fishery index is the cumulative catch per 1,000 fathom-minutes over that period. Index values in 1998 were considerably higher than in 1997. Overall, the index value has been declining since the mid-1960s, although there is considerable variability. From 1965 to 1996 the finite rate of decrease was 5 per cent and the generational rate of decrease was 15.5 per cent. These are similar rates to those observed for Babine escapement and total stock size, and for the Upper Skeena average escapement. The origin of the coho caught in the test fishery is uncertain, but until the end of August most are believed to be coho from the Skeena above Terrace. Stock composition in this fishery is currently being examined using DNA techniques.

The third index of status is derived from visual counts of spawners made in many streams in the Skeena River drainage since 1950. Although few systems have been consistently counted, the many counts that are available can be combined into an index of abundance. This relative index has been generated for systems in the Upper Skeena (upstream of Terrace, excluding the Kispiox), and the lower Skeena (all other Skeena streams). For comparative purposes the same index has been calculated for southeastern Alaskan streams, and streams in the Nass/Portland, Principe/Grenville and Kitimat areas.

One of the interesting aspects of these escapement records is the regional variation in the escapement shortfall in 1997. This event was most severe in the Upper Skeena and in Area 6, least severe in Area 3 and in southeastern Alaska, and detectable on the central coast as well. The 1997 event was caused by abnormally poor marine survival of smolts entering the ocean in 1996, which occurred over a broad area.

The most fragmented and sparse escapement records are from the Upper Skeena. Escapements in this area fell during the 1980s and 1990s and reached a low point in 1997. The recovery in 1998 to near-average escapement levels reflects in part a real increase in escapement but also an increase in counting effort. Escapement to the lower Skeena has not varied much over time, recovering from a record low in 1997 to a near-average value in 1998. Escapement to the region to the southwest of the Skeena (Area 5) decreased precipitously in 1969 but has remained relatively stable since then, although the quality of data in this area is particularly poor and may not be reliable. Escapement to streams in the Kitimat area appears to have decreased steadily since the late 1960s. There may be serious conservation problems in this region. In contrast, escapement is robust in the Nass/Portland area and in southeastern Alaska.

The last of the four indices of status is the density of juvenile coho in late summer. Pool habitats in small streams throughout the watershed have been sampled since at least 1994 and in some areas since the late 1980s. Densities in excess of 0.75–1.0

juveniles per square metre are considered indicative of full "seeding". Fully seeded streams received enough spawners to populate preferred habitats with juveniles and, under average conditions, should produce near-maximum numbers of smolts.

Juvenile densities in most of the Upper Skeena (the high interior, the Babine, and the Upper Bulkley) are low, and in two of the three areas were nearly absent in 1998. Densities in the Morice drainage are considerably higher. Fairly high densities have been consistently recorded in Morice River side channels. Comparable densities have been observed in the streams around Terrace and in coastal streams. High densities have been observed in Kispiox streams and in the Lachmach River, so only these two areas might be considered adequately seeded. The low numbers of juveniles observed in 1998 in the streams of the Upper Skeena is consistent with the poor escapements observed in 1997. However, strict restrictions on coho fishing in 1999 resulted in improved spawning escapements. In some areas, including the Skeena River system, improvements appear to be substantial – almost two times the average for the decade.

In 2000, the in-season estimates of upper Skeena coho indicated an above average marine survival rate, and the test fishery indicated the index of abundance was significantly higher this year than in 1997 (the brood year) and slightly above the 1990s. This is a positive sign, considering the brood year for 2001's returning fish (1997) was one of the lowest on record.

The four indicators of coho status demonstrate that populations in the Upper Skeena are depressed and at levels well below historical abundance. Populations in the lower and middle Skeena appear to be healthy in comparison, although there may be localized exceptions. Coastal populations north of the Skeena, especially those in southeastern Alaska, appear to be robust while those to the south appear to be as depressed as those in the Upper Skeena.

Indicator Streams

Wild smolts leaving the Lachmach River and hatchery smolts produced at the Toboggan Creek hatchery have been coded-wire tagged since 1987. Counts of the number of tagged fish that have returned to each location have been made since 1988. Those counts, combined with estimates of the numbers of tagged fish caught in marine and freshwater fisheries, allow the estimation of the smolt-to-adult survival rate (the proportion of smolts that survive to the fishery and escapement) and the exploitation rate (the proportion of those survivors that are caught).

Total exploitation of the Lachmach population varied from 62–76 per cent between 1988 and 1996. Restrictive measures in Canadian fisheries reduced the exploitation rate to 56 per cent in 1997 and complete closure of the commercial fishery reduced the exploitation rate to 46 per cent in 1998, almost all of which was in Alaskan fisheries. Total exploitation of the Toboggan Creek coho ranged from 41–73 per cent between 1988 and 1996. With complete closure of the commercial fishery in 1998 total exploitation was 28 per cent.

Differences in the total exploitation rates between the two stocks can be attributed to several factors. Toboggan Creek coho have a more southerly distribution than Lachmach coho. Consequently, measures taken in the Canadian northern troll to reduce impacts on Upper Skeena coho taken throughout the 1990s have had proportionately more effect for Toboggan coho. Larger impacts of freshwater sport and First Nations' fisheries offset that difference to some extent. Tagging information available for Babine Lake coho suggests that the ocean distribution of these populations is similar to that of Lachmach coho. That similarity would reduce the benefits of management actions in Canadian fisheries and might explain why the estimated exploitation rate on Babine coho in 1998 was 60 per cent.

Smolt-to-adult survivals have averaged 8.5 per cent for Lachmach River coho but only 2.9 per cent for Toboggan Creek. Over the past four years it has been possible to estimate the number of wild smolts leaving Toboggan Creek. Using that estimate along with counts of wild coho in the escapement fisheries scientists have been able to estimate the survival rates of wild coho, which have averaged 11 per cent. Variations in survival rates are similar for all sites, suggesting that they have common causes. The significantly lower survival value in 1997 (the 1996 smolt year) suggests that marine survival was the likely cause of the escapement shortfall in that year. Survivals rose to near-average levels for the coho returning in 1998.

The productivity of a fish population determines how many adults can be harvested on a sustained basis. Such characterizations are subject to many uncertainties but we do know enough about the coho populations of the Skeena and surrounding regions to be able to compare their productivity. One approach to characterizing productivity gives estimates of the Maximum Sustained Yield (MSY) and the exploitation rate at which that yield occurs. For any population there is an estimate of the number of spawners required to produce the MSY. The exploitation rate at MSY varies from 56 per cent for Kitimat area streams to 83 per cent for a coastal Alaskan indicator stream. Status varies directly with productivity. The one exception is the enhanced Toboggan Creek population, which is supplemented by surplus hatchery spawners.

Outlook

The reappearance of detectable numbers of adult coho in most areas of the Upper Skeena in 1998 is a promising indication that the long-term decline in these populations can be reversed through conservation-minded fisheries management. The time for recovery of coho in the Upper Skeena will depend on continued moderation of fishing pressures and continued favorable ocean survival rates. Under those conditions, Upper Skeena coho should recover to healthy levels within two to three cycles, or within nine years.

Actual Canadian exploitation rates for Upper Skeena coho were reduced to about 3 per cent in 1998 and 1999 and were in the order of 6 per cent in 2000, from the 30 to 40 per cent range prior to 1998. The management approach for 2001 will be to conduct fisheries in a manner similar to previous years, with flexibility for more opportunities if in-season abundance is sufficient. This approach recognizes that in 2000 high levels of escapement were observed in many portions of the Skeena River. As the stocks are still in their rebuilding range, fishing opportunities will be designed to minimize impacts on Upper Skeena coho.

PINK SALMON

Pink salmon (*Oncorhynchus gorbuscha*) are the most abundant of the six species of Pacific salmon. As adults they are also the smallest, averaging 1–2.5 kg. A peculiarity of the species is its fixed two-year life span. After emerging from the gravel where they were spawned, fry swim quickly to sea and grow rapidly as they make extensive feeding migrations. After spending 18 months in the ocean, the maturing fish return to their natal rivers to spawn and die. Because of their fixed two-year life cycle, odd- and even-year stocks spawning in the same stream are reproductively isolated from each other and represent genetically different lines.

In spite of their short life span and relatively small size, pink salmon migrations are extensive, covering thousands of kilometres from their natal streams. In the Northeastern Pacific, they are found from California to the mouth of the Mackenzie River, although the major spawning grounds are located between Puget Sound, Washington and Bristol Bay, Alaska. During the ocean feeding and maturation phase, they are found throughout the North Pacific and Bering Sea north of 38°N in the western part, and 42°N in the eastern part. During fall and winter, pink populations are distributed in the southern part of their range.

The Fraser River system was one of the world's most productive areas for pink and sockeye salmon prior to 1913, when railway workers dumped millions of tons of rock into the Fraser at Hell's Gate Canyon. The following year, huge slabs of rock loosened by blasting fell into the narrow gorge, blocking the flow and preventing pinks and sockeye from reaching spawning areas further upstream. While many stocks of pink salmon drastically declined or disappeared, the installation of fishways in later years has been successful, with some stocks greatly improving.

When young, pinks are silver with no parr markings or spots as seen on other salmon. As they mature, they develop blue backs with heavy oval blotches on the tail and upper body. Pink salmon are commonly known as "humpbacks" or "humpies" because of the extremely humped back developed by males as they return to spawn. During spawning, both sexes change from the blue and silver colours of the ocean to pale grey on the back with a white to yellowish belly.

Most pink salmon are canned, although in recent years many, especially from the troll fishery, have been frozen.

Central Coast Pink Salmon

Background

The central coast of B.C. (Areas 7–10) has more than 130 streams and rivers supporting populations of pink salmon. Central coast streams support both odd- and even-year stocks. Since 1960, total returns among monitored streams indicate that even-year pinks are usually more abundant than odd-year fish. Area 8 encompasses more than 40 pink salmon streams, which account for well over 75 per cent of total regional returns. Within this area, the Bella Coola/Atnarko River system supports the largest populations of pink salmon, with recent (1990-96) even- and odd-year escapements numbering as high as 3.1 million and 2.2 million fish, respectively. This system often accounts for more than 50 per cent of the central coast pink escapements.

The Kwatna, Koeye and Kimsquit rivers are also important pink salmon producers in the central coast. Areas 7 and 9 each produce in the order of 200,000 to 300,000 fish annually. Area 7 contains over 60 pink-producing streams, though none of these support large populations. Area 9 contains fewer than 25 pink streams, with the Chuckwalla and Kilbella rivers supporting moderately large populations. Area 10 contains fewer than 10 pink streams, all supporting relatively small populations.

For management purposes, both catch and spawning escapement data are used as indicators of stock abundance. Each area contains key streams whose escapements are actively monitored in-season to determine run timing and size. This is accomplished through visual counts of fish in streams, either from the air or by walking the streams. Escapements to most other pink streams are also monitored, and generally follow the same abundance trends as those in key streams. Commercial catch per unit effort is monitored as an indicator of overall pink abundance. This information provides managers with an indication of whether target escapements will be met, and hence which harvest strategies will be permitted. Stock-recruitment relationships are also used to provide forecasts of run size. In addition to adult enumeration, hydraulic sampling of the Atnarko River and spawning channel is carried out in the fall and spring to estimate overwintering mortality. Such mortality can be high during unusually high or low flow conditions.

Returns of pink salmon to the central coast over the past 36 years have been highly variable in all areas, in both even and odd years. As recently as 1988, returns peaked at over 15 million fish. Returns over the last several odd- and even-year cycles have been declining in some areas. The Bella Coola/Atnarko River system suffered a large decline from more than 3 million fish in 1992 to fewer than 500,000 fish in 1994. However, 1996 returns increased to 1.2 million fish. In fact, 1996 returns indicate that populations throughout the central coast are again rebounding. Escapements reached record levels in over half a dozen systems, including the Koeye, Kwatna and Chuckwalla rivers. While odd-year returns have declined recently in some systems, returns were not low by historical standards.

Fishery Management

For much of this century, the central coast has been an important area for commercial catches of pink salmon. Catches reached a record high of 13.5 million fish in 1962. In 1983, in order to minimize interceptions of Fraser River pink and sockeye, the fishery was moved further inshore, thus creating a more terminal fishery.

Area 7 provides limited commercial fishing opportunities for a small fleet on a mix of numerous small stocks. The Area 8 pink fishery is dominated by the Bella Coola/Atnarko River stock, but also harvests a Koeye River stock. Occasionally, when target escapement goals are met, small targeted fisheries are permitted in Areas 9 and 10.

There is no directed aboriginal food fishery for pink salmon on the central coast, though some pink are caught incidentally during fisheries for other Pacific salmon. The same is true for the recreational fishery, though pinks will sometimes be targeted when chinook and coho catch rates are poor.

Outlook

Even-year central coast populations may be increasing after several cycles of low abundance. As predicted, increased returns for odd-year pink salmon stocks in Areas 8 and 9 provided commercial fishing opportunities in 1999. Seine fishers caught 4.7 million pinks, the bulk of the central coast catch of all gear types. This was contrasted in 2000 with below average fishing opportunities due to concerns of stock abundance of other species. The commercial fishing sector will have selective fishing opportunities for pink salmon in Area 8 in 2001. The conservative harvest management approach currently in place in this region appears to be effective in conserving pink salmon, and should ensure their long-term viability.

SOCKEYE SALMON

Best known of the Pacific salmon, sockeye salmon (*Oncorhynchus nerka*) occur throughout the temperate North Pacific Ocean, and are the most sought after for their superior flesh. Although all Pacific salmon feed on shrimp and other crustaceans, these constitute the main diet of sockeye salmon, which may account for their rich colouration and high oil content.

Sockeye spawn in rivers and lakes from the southern Kuril Islands north to Kamchatka on the Asian coast, and from the Columbia River north to Alaska on the North American coast. Most spawn in rivers that feed into lakes, or in the outlets and spring-fed beaches of lakes, sometimes as far as 1,600 km from the sea. In B.C., major spawning runs of sockeye are found in the watersheds drained by the Fraser, Skeena and Nass rivers, and those of Rivers and Smith inlets.

These far-ranging fish exhibit remarkable variation in life history. However, they typically emerge from nests in gravel as free-swimming fry in the spring, spend one or two years rearing in a freshwater nursery lake, and then migrate to the ocean where they spend another two or three years before returning to their natal stream to spawn and die. Five- and six-year old sockeye are common, but in northern rivers, some eight-year-olds are found.

Adult sockeye are attractive fish with silvery bodies and blue-green backs, faintly speckled with black. As sockeye approach their natal steams, they turn varying shades of red, and the males develop large teeth and hooked jaws. Their size varies with age, with four-year old sockeye averaging 3 kg, while older fish run to 5.5 kg.

In commercial fisheries, sockeye salmon are caught by gill nets, purse seines and trolling gear. In addition there is a significant First Nations food fishery in some rivers. Sockeye were the first salmon to be canned in quantity and remain the mainstay of the canning industry.

Fraser River Sockeye

Background

Cyclic fluctuations in abundance are characteristic of many fish populations with a single predominant reproductive age. Fraser sockeye salmon mainly mature and spawn at age four, and of approximately 20 sockeye populations in the Fraser River watershed that are enumerated routinely, eight exhibit persistent four-year cycles with a predictable dominant-year cycle line every four years, when the run size is persistently larger than the other cycle lines. The 1998 cycle or cycle line refers to the sequence of years 1998, 1994, 1990, through to 1902, and so on. Run size is persistently lowest during off-year cycle lines and intermediate on the subdominant cycle line.

The processes that maintain population cycles in Fraser River sockeye are poorly understood. Hypotheses to explain the cycles centre on identifying agents that impose higher mortality when abundance is low than when abundance is high (i.e. depensatory mortality). Various ecological hypotheses have been proposed that theorize predation during early sockeye freshwater development is depensatory. Other explanations centre on evidence for depensatory fishing mortality. Despite intensive investigations on the subject, scientists have failed to reach consensus on the causes of cycles in Fraser River sockeye.

Considerable evidence has been compiled to suggest that the 1901 cycle line had persisted as the dominant cycle line since the time of the first Hudson's Bay Company records (1820), and perhaps since the first reference to Fraser River sockeye (1793). Company records prior to 1873 indicate that all the major Fraser River sockeye runs exhibited four-year cycles, with the dominant cycle occurring in the same year. Later B.C. Ministry of Fisheries documents also confirm that spawning abundance to the upper Fraser River populations cycled in synchrony between 1901 and 1913. Estimates of the number of spawners on the 1901 line up to 1913 (1897–1913) range from 5 million in 1909 to 13 million in 1901. The International Pacific Salmon Fishery Commission (1973) reported catches of 35 million in 1913. Dominant runs prior to 1913 may have been about 100 million sockeye.

Because of obstructions in the Fraser canyon at Hell's Gate, most sockeye returning to the Fraser failed to reach the spawning grounds in 1913 and consequently the 1901

(1997) dominant cycle was lost. So, too, ended the synchrony in the temporal pattern of cycles among cyclic populations. The build up of runs in the years that followed eventually resulted in less pronounced differences in sockeye abundance among the four cycle lines. Individual runs rebuilt beginning in 1926, with large increases to the Lower Adams River on the 1998 cycle line. Spawning stock size for other runs began to increase in the 1930s. Sustained increases in all runs, however, were only achieved following construction of fishways in the Fraser Canyon along with a five-year fishing closure on early and mid-season run timing groups during 1946–50.

Historically, the dominant run of Adams River (Shuswap Lake) sockeye has been the single largest spawning population in the Fraser River watershed and the main contributor to the 1998 cycle line. The cyclic pattern of Adams River sockeye is remarkably persistent, with roughly an order of magnitude decline between successive years within the four-year cycle. Other important stocks on the 1998 cycle line are Chilko and Quesnel Lake sockeye. The contribution of these two stocks to the 1998 cycle line has increased relative to the Adams/Shuswap stock in recent years. Following the 1913 collapse, the 1998 cycle line rebuilt to be the most abundant cycle line until the 1990s, when the abundance of 1997 cycle line surpassed the abundance of the 1998 line.

The rapid rebuilding of the 1998 cycle line that occurred between 1930 (5.5 million) and 1958 (19 million) was temporarily halted following high mortality of the 1958 year class. The run size of returns in 1962 was only 3.5 million sockeye. The 1998 line since rebuilt to a maximum of 22 million sockeye in 1990. The spawning escapement in that year was 6 million sockeye. In 1994, the total sockeye return was estimated at 17 million with a spawning escapement of 3 million. Major discrepancies in estimates of run size and low spawner abundance of Adams/Shuswap Lake sockeye in 1994 led to the formation of the Fraser River Sockeye Public Review Board.

During the summer migratory period in 1998, the potential for devastating effects of record-high water temperatures in the Fraser River watershed on survival prompted remedial in-season management action to reduce harvest rates and increase spawning escapement. By the end of the fishing season there was a discrepancy of 3.5 million fish between estimates of fish passage in the lower Fraser River at Mission and up-river estimates of catch-plus-spawning escapement. Despite a review of the possible causes of the discrepancy conducted jointly by Fisheries and Oceans Canada and the Pacific Salmon Commission, it is not known whether the apparent loss was due to natural causes brought on by the high water temperatures or other factors. Including the discrepancy, the run size in 1998 was 10.9 million sockeye. This was the lowest abundance on the 1998 cycle since 1978. The estimated spawning escapement in 1998 of 4.4 million sockeye was the second largest reported on the cycle and the third largest for all years (1938–98).

Fraser River sockeye have been remarkably productive as measured by the ratio of adult recruits produced for each spawner. An average of four adult recruits were produced per spawner for the Adams/Shuswap stock on the 1998 cycle line since 1948. For that stock, productivity has been highly variable, ranging from less than one to eight recruits per spawner. For most sockeye populations, there is little evidence of diminishing adult returns at the upper range of spawning stock sizes observed. This is true for Adams/Shuswap sockeye. For some stocks we have seen lower return rates in a few years of high spawning stock sizes. Because of high survival variability, independent of the number of spawners, repeated high spawning levels are required to assess optimal stock sizes under average conditions.

Trends in recruitment at any particular spawning stock are not only affected by random inter-annual variations in survival but also by long-term climatic variations in productivity. Until spawning stock sizes recur at sufficiently high levels, the full potential of Fraser River sockeye will not be known.

Sockeye returns to the Fraser River were much lower than expected in 1999 resulting in the closure of most commercial fisheries. However, in 2000, returns were much stronger than forecast and resulted in modest fishing opportunities resulting in a total catch of 548,000 fish.

The preliminary estimate for Fraser River sockeye in 2001 suggests a strong run size, which should allow for a significant catch in Canadian fisheries. The total allowable catch will depend on run size and escapement objectives, as well as by-catch concerns.

Fishery Management

Prior to the advent of commercial fishing, Fraser River sockeye were a critically important food resource for both aboriginal peoples and early Hudson Bay traders. Following construction of the first cannery on the Fraser River in 1866, the commercial gill net fishery developed rapidly. The early commercial fishery was intense and harvest rates on the non-dominant cycles were higher than on the dominant (1901) cycle. Thus it seems likely that cyclic trends in Fraser sockeye production prior to 1913 were exaggerated and at least partially maintained by different fishing patterns among cycles (e.g. depensatory fishing mortality).

The amount of catch taken before the advent of the commercial fishery is unknown but presumably it was small compared with the commercial catch. Reconstructed estimates of commercial catches ranged from 35–50 million fish per year on the 1901 (1997) line before 1913. Estimates of catches on the 1902 (1998) cycle line ranged from 4–7 million fish per year.

As a result of habitat destruction, the most notable being the effects of the Hell's Gate slide in 1913, and the overfishing in the years that followed, catches on the dominant 1901 line abruptly declined. Catches on the 1998 cycle line declined from 5.7 million sockeye in 1914 in one generation to 800,000 sockeye in 1918. Between 1918 and 1958, catches on the 1998 line gradually increased to 15 million sockeye. Catches in 1962 dropped to less than 2 million sockeye but increased to 16 million in 1990. Catches in the two most recent cycle years (1994 and 1998) were 13 million and 3 million.

In response to the extreme water temperatures in the Fraser River watershed in 1998, harvest rates were reduced to increase spawning escapement levels. The harvest rate on the 1998 cycle averaged 69 per cent between 1954 and 1998. The harvest rate was deliberately reduced in 1962, 1966 and 1970 to rebuild the 1998 cycle following the high mortality of the 1958 year class. The harvest rate of 28 per cent in 1998, based on a run size that includes the discrepancy of 3.5 million fish, was the lowest on record since 1946.

During 1937–84, the International Pacific Salmon Fishery Commission (IPSFC) was responsible for management of fisheries in a "Convention Area" that included Canadian and U.S. fisheries in southern B.C. and Washington State waters. During that period catches from Convention Area fisheries were shared equally between Canada and the United States. With ratification of the Pacific Salmon Treaty in 1985, the Fraser River Panel under the auspices of the Pacific Salmon Commission has regulated management of Fraser sockeye fisheries.

The Fraser River Panel consists of Canadian and U.S. representatives. Its purpose is to ensure spawning targets set by Canada, and international and domestic catch allocation goals are met. Following several years in the of managing Fraser River sockeye fisheries without a Canada-U.S. agreement on catch sharing, a new long-term agreement was endorsed in 1999. The U.S. share phased in over the next few years will be fixed at 16.5 per cent. This compares with the historical average agreed share of 20.5 per cent between 1985 and 1996.

Canadian commercial catches have mainly been taken in the troll fishery off the west coast of Vancouver Island, purse seine and gill net fisheries in Johnstone and Juan de Fuca straits, and the gill net fishery in the Fraser River. Smaller commercial fisheries also occurred in northern and central B.C. and within the Strait of Georgia. In 1998, the Canadian commercial catch was 2.2 million fish. The proportion of Canadian commercial catch by gear in 1998 was 32 per cent troll, 34 per cent purse seine, and 34 per cent gill net.

Sockeye are harvested in First Nations food fisheries throughout the Fraser River watershed. The Canadian First Nations catch in 1998 was 844,000 sockeye. Recreational catches are presently small but estimates of sports catches have recently increased. U.S. fisheries occur mainly in the net fisheries in Juan de Fuca Strait and southern approaches to the Fraser River located in U.S. waters. Some Fraser sockeye are also taken in southeastern Alaska. The total U.S. catch in 1998 was 708,000 sockeye.

Historically, economic yield from the 1998 cycle line has mainly come from the dominant Adams/Shuswap stock. The rapid rebuilding of Chilko and particularly the sub-dominant Quesnel Lake stock in recent years indicates larger economic returns on this cycle are likely. Much larger gains on the 1998 cycle depend on the extent to which other runs can be rebuilt.

In the summer of 1999, lower than expected returns prompted the complete closure of the Fraser River sockeye fishery.

Outlook

The current lack of understanding of the processes that maintain cyclic patterns in Fraser River sockeye is undoubtedly the single greatest obstacle to maximizing Fraser sockeye potential. Even under pessimistic scenarios, increases in yield should result from increases in spawning abundance to off-cycle runs. If strong dominant-year cycle lines act to suppress other cycle lines, then it might be advisable to limit the abundance of the 1998 cycle at an intermediate level to create greater biological opportunity for the off-year cycle lines. Certainly, there is no evidence to indicate the current cyclic pattern is optimal. For the Adams/Shuswap stock complex, the low cycle years (2000 and 2001 cycle lines) have persisted at low levels despite population growth on the dominant and sub-dominant cycles. Ultimately, the processes that perpetuate population cycles and prevailing climatic factors affecting survival will determine the rate that low runs can be rebuilt to optimal long-term levels.

West Coast Vancouver Island Sockeye Salmon

Background

More than 20 distinctive stocks of sockeye originate from the west coast of Vancouver Island (WCVI). However, more than 80 per cent of all WCVI sockeye, taken as catch prior to the end of July, originates from stocks returning through Barkley Sound to Great Central, Sproat and Henderson lakes. Barkley Sound sockeye have been the subject of more than a century of management, research and enhancement activities. From 1890 to 1972, average returns were less than 100,000 fish. From 1972 to present, however, lake fertilization and management designed to increase spawner abundance have been used to increase production of Barkley Sound sockeye, and harvests alone now average more than 400,000 fish. Although other WCVI sockeye, such as the Hobiton, Kennedy, Megin and Muchalat stocks, are too unproductive to support commercial harvests, they remain important to First Nations people for food, ceremonial and social purposes.

Recently, production and catches of Barkley Sound sockeye have declined dramatically. Research by Fisheries and Oceans Canada has shown that marine growth and survival of WCVI sockeye, including those from Barkley Sound, are sensitive to periodic variations in ocean climate that occur at intervals of three to 20 years.

Recurring shifts in ocean climate result in changes in community structure and productivity of both coastal and offshore ecosystems where WCVI sockeye spend one to three years of their life. Consequently, returns of several WCVI sockeye stocks (Barkley Sound and Hobiton, for example) fluctuate together.

Marine conditions are especially unfavourable for juvenile sockeye survival when coastal ocean temperatures are high and salinities are low because migratory predators, including Pacific hake and mackerel, arrive earlier and in greater abundance in such years. Pacific mackerel reached such high abundance during recent warm El Niño summers that ocean survival of sockeye that migrated seaward during these years are the lowest on record for WCVI stocks. Indeed, strong El Niño events accompanied by above-average temperatures in the nearshore marine environment have been followed two and three years later by declines in sockeye returns throughout the 100-year period of records for Barkley Sound sockeye. Research conducted over the past 15 years suggests that juvenile sockeye migrating seaward from WCVI nursery lakes experience survival rates two to five times higher during years when the coastal ocean exhibits cool, high-salinity waters compared with years when coastal waters are warm and less saline.

Rapid changes from one ocean climate state to another can lead to steep increases or dramatic "crashes" in WCVI sockeye returns. Prior to the 1992–94 El Niño event, for example, Barkley Sound sockeye returns peaked at almost 2 million fish in 1991 followed by a 10-fold decline to only 200,000 returning fish in 1995. Although Barkley Sound sockeye returns have remained high enough in most recent years to satisfy spawning requirements as well as support aboriginal, recreational and commercial harvest, stock declines associated with the recurrence of strong El Niño events have been severe enough to entirely eliminate commercial harvest there in 1989, 1990, 1995 and 1996. These same events have likely contributed to simultaneous declines from thousands of adults to record lows of fewer than 100 adults returning to each of several small WCVI stocks (e.g. the Muriel Lake and Clayoquot Arm stocks in the Kennedy Watershed) even in the absence of any exploitation.

Barkley Sound and other WCVI sockeye stocks exhibit highly variable returns in response to a multitude of natural or man-induced changes in environmental conditions in both the freshwater and marine ecosystems they occupy throughout their life history. Future returns may be expected to exhibit even more extreme interannual to interdecadal variations because WCVI sockeye stocks reside at the southern end of the range for the species, where they are likely to be especially sensitive to climate change, such as global warming or cooling, and the increasing influence of human populations on critical freshwater and coastal marine habitats.

Understanding of the complex mechanisms that control both short- and long-term variations in salmon returns is still rudimentary. For example, the collapse of the Clayoquot Sound sockeye stock in the early 1970s or its failure to recover in the absence of commercial exploitation for the past 25 years has not yet been explained. Research conducted by federal fisheries scientists over the past decade, however, has provided a basis for new procedures to forecast annual return variations of WCVI sockeye. Recent forecasts of total returns of sockeye are based on models that account for annual variations in marine survival, as well as the abundance of juvenile sockeye migrating seaward from various nursery lakes. Marine survival predictions are based on direct observations of strong associations between coastal ocean climate indicators (salinity and temperature during ocean entry by juveniles) and return rates. Pre-season forecasts generated annually since 1988 have been applied with excellent success by fisheries managers to anticipate when to plan for either strict stock conservation or progressive harvest measures for WCVI sockeye.

Fishery Management

From the late 1800s to the mid-1900s, terminal net fisheries harvested small quantities of sockeye from several WCVI stocks to supply canneries at Nitinat Inlet, Barkley and Clayoquot Sounds. The two largest fisheries occurred in Clayoquot and Barkley Sounds, where average annual harvests ranged from 27,000 to 89,000 fish. Smaller quantities were harvested principally for subsistence purposes at other WCVI sites.

Although Clayoquot Sound once supported the largest WCVI sockeye fishery, persistent stock declines since early in the century led to the collapse of the fishery in the mid- to late 1970s. Stock declines appear to have been related to over-exploitation and unfavourable environmental conditions in both freshwater and marine environments. In spite of 25 years of continuous closure to commercial fishing, these stocks have failed to recover.

The history of Barkley Sound sockeye stocks and fisheries contrasts sharply with that of Clayoquot Sound. The Clayoquot Sound fishery has passed through several phases including a largely terminal subsistence fishery that probably harvested no more than 50,000 sockeye per year (pre-1900); a terminal beach seine and gill net fishery that provided catches as high as 125,000 sockeye (1900–40); a more diffuse gill net fishery that exploited mixtures of sockeye in Alberni Inlet and the outer waters of Barkley Sound yielding catches of 5,000 to 76,000 sockeye (1940–70); and, finally, a mixed-gear, mixed-stock fishery in which gill net, purse seine, recreational and aboriginal fisheries harvest an average of more than 400,000 sockeye per year (1971–98).

Barkley Sound sockeye are currently managed to meet a target of no less than 200,000 adult spawners to ensure long-term sustainability of the stocks, provide for the food, ceremonial and social needs of aboriginal peoples, and create and identify opportunities for surplus sockeye to be taken by recreational and commercial fisheries.

On at least three occasions, habitat protection measures have prevented the almost certain destruction of one or more of the Barkley Sound sockeye stocks. Gear and area restrictions within the commercial fishery have been used with varying effectiveness throughout the past century to focus exploitation or stock rebuilding efforts alternately on Henderson, Great Central or Sproat Lake sockeye. Stock development and enhancement activities have included: removal of obstructions to fish passage (1901, 1903, 1912–16, 1936); construction and maintenance of fishways at Stamp Falls (1927, 1954), Sproat Falls (1951), and the outlet of Great Central Lake (1929, 1957); operation of a sockeye hatchery on Henderson Lake (1909–35, 1993–98); and fertilization of Great Central (1970–73, 1977–98), Henderson (1976–98) and Sproat lakes. Lake fertilization in combination with management to increase spawner abundance has been used to increase the production of Barkley Sound sockeye to historically unprecedented levels and has made them the focus of major aboriginal, recreational and commercial fisheries since the early 1970s. However, it is doubtful that this would have been achieved in the absence of the other stock protection and enhancement activities that have contributed over the past century to the maintenance or development of Barkley Sound stocks.

Outlook

From 1997–99, the waters on Canada's west coast exhibited a dramatic swing from the extremely warm, low salinity conditions associated with a strong El Niño to the extremely cold, high salinity conditions associated with a strong La Niña event. In addition, estimates of juvenile sockeye production were average to above average for these years. Consequently, Barkley Sound and WCVI sockeye returns until 2001 are anticipated to fluctuate, but allow modest commerical fishing activity. The commercial harvest of Somass River sockeye (Barkley Sound) in 2000 was significantly lower than anticipated because the returns were less than expected (375,000 vs. 532,000). The Area D gillnet fleet harvested approximately 16,000 and the Area G troll fleet harvested about 5,000. First Nations food, social and ceremonial fisheries occurred in outer Barkley Sound and accounted for a harvest of about 14,000 sockeye, and the pilot sales in the Somass River fishery resulted in catches of 37,000. Similar commercial fishing opportunities are expected for 2001.

Smith Inlet and Rivers Inlet Sockeye Salmon

Background

Sockeye salmon production from Smith Inlet (Area 10) is managed as a single stock. Spawning occurs in tributaries to Long Lake, a clear nursery lake with a surface area of 21 square kilometres. As in most coastal sockeye stocks, natural productivity is limited by the availability of nutrients in the nursery lake. Long Lake has been fertilized artificially in most years since 1976 to enhance production. Spawning escapements and juvenile recruitment have been monitored more intensively there than elsewhere on the central coast. Total adult returns have averaged 333,000 fish annually since reliable counts began in 1992.

Spawning escapements to Long Lake have been enumerated reliably since 1972. After the target was increased in 1979, escapements roughly doubled from the average recorded in previous years. Total sockeye salmon returns generally increased over the same period, setting records of more than 800,000 fish in 1991 and 900,000 in 1992. However, total returns declined dramatically in 1994 and have not been sufficient to meet the escapement target since. This decline was caused by poor marine survival of the 1990 and 1991 brood years, which migrated to sea in 1992 and 1993. In fact, hydroacoustic surveys of juvenile abundance reveal that these brood years experienced above-average survival in fresh water, and produced above-average recruitment of pre-smolts.

Sockeye production from Rivers Inlet (Area 9) is also managed as a single stock. Spawning occurs in at least 12 tributaries to glacially turbid Owikeno Lake. This nursery lake is large by coastal standards at 96 square kilometres, but its productivity is low because of poor light penetration rather than the availability of nutrients. The glacial turbidity of the lake and its major spawning streams also precludes reliable estimation of spawning escapements by visual survey. Nevertheless, sockeye returns are estimated to have averaged 924,000 fish since 1948.

Since the total spawning escapement to Owikeno Lake cannot be enumerated reliably by visual survey, historical estimates should be considered only as rough indices that may greatly underestimate or overestimate actual escapements. Even so, these estimates indicate that escapements generally increased as a result of fishery restrictions imposed in 1979, and that the new escapement target was achieved every year thereafter until 1994.

However, increased spawning escapements did not lead to a demonstrable increase in total adult returns. In fact, total returns appear to have decreased since the decision to increase escapements by reducing catch. Existing data are inadequate to determine whether the decline prior to 1994 was real or simply an artifact of reducing the catch-escapement ratio, given that catch is known reliably but escapement may be underestimated. In any case, there can be little doubt that total returns declined dramatically in 1994 and since then have not been sufficient to achieve the target escapement. Juvenile abundance indices, based on sporadic trawl surveys or inferred from pre-smolt size data, show no overall decline in freshwater survival or pre-smolt production.

As in Long Lake, pre-smolt production from the 1991 brood year was above the long-term average, implying that this brood suffered high mortality during or after seaward migration.

Fishery Management

The sockeye fishery on the Smith and Rivers inlets stocks began in the late 19th century and increased rapidly during the first decade of the 20th century. As boats became faster and more mechanized, the fishery moved out of the inlets and farther offshore. Starting in the early 1970s, fishing boundaries were moved progressively shoreward creating more of a terminal fishery. Since 1985, all net fishing has occurred inside the inlets.

Prior to 1972, annual catches of Smith Inlet sockeye salmon averaged 248,000 fish. The installation of the Docee Fence in 1972 allowed reliable in-season enumeration of escapements to Long Lake, and this provided a basis for managing the sockeye fishery in-season. Annual catches averaged 162,000 sockeye from 1972–78. Returns from the lake fertilization program were evaluated in 1979 and the escapement target was increased to 200,000. Annual catches from 1979–96 have averaged 202,000. Sockeye catches in Smith Inlet during the 1995 and 1996 fishing seasons were unusually low due to poor marine survival of the 1990 and 1991 brood years.

Annual catches in Rivers Inlet averaged 808,000 sockeye prior to the implementation of an adaptive management plan in 1979. This plan restricted fishing effort and, from 1979–96, average annual catch decreased to 150,000. Prior to 1979, the Rivers Inlet sockeye stock was managed to various target escapements. Since 1979, fishery managers have adopted harvest rate targets that vary with stock size and established a minimum escapement target of 200,000 sockeye. Harvest rates and subsequent escapements are regulated by a series of weekly commercial openings, with the number of days open determined by a combination of pre-season forecasts and in-season adjustments based on catch rate information from the commercial fishery. Because recent declines are attributed to poor marine survival experienced by stocks in both Smith and Rivers inlets, the Docee Fence count in Smith Inlet has been used as a trigger for initiating the Area 9 fishery. As a result, no commercial gill net fishery was permitted in Area 9 in 1996; this closure was appropriate given that the total return to Rivers Inlet was less than half the target escapement.

Outlook

The coincidence of declining returns to both Smith Inlet and Rivers Inlet suggests that both stocks have experienced the same unfavourable marine conditions. Marine survival indices for the two stocks were highly correlated in the four brood years for which data are available from both lakes. Recent marine conditions are generally considered to be anomalies from the long-term average, and are expected to moderate in the near future. However, prudence demands that these stocks be managed to rebuild escapements, and that management plans assume that poor marine survival may continue.

Returns in 2000 indicated the situation has worsened and have necessitated more strategic protective and rebuilding measures.

Skeena River Sockeye Salmon

Background

In Canada, the Skeena River is second only to the Fraser River in its capacity to produce sockeye. At least 70 distinct spawning sites and 27 lakes are used by sockeye within the Skeena watershed. These nursery lakes are distributed from the coast to the high interior regions and vary widely in size and productivity. The Babine-Nilkitkwa lake system, which covers 500 square kilometres, is the largest natural lake in B.C. and supports the largest single sockeye salmon population in Canada. The Babine population has accounted for 75 to 95 per cent of Skeena sockeye salmon production, averaging more than 3.8 million adult fish annually since 1990. Fry recruitment is greatly enhanced by spawning channels in the Fulton River and Pinkut Creek, which typically account for more than 70 per cent of smolt production from the Babine-Nilkitkwa lake system.

Skeena River sockeye smolts migrate to sea in late April through June, then move northward along the coast and offshore into the North Pacific Ocean. Most mature at age four or five, although males ("jacks") commonly mature at age three. The maturing fish return from offshore waters of the North Pacific Ocean through southeastern Alaska and enter the Skeena terminal fishing areas from late June through mid-August. (The run typically peaks on July 23.) Spawning occurs from late July to October, but timing differs among populations largely as an adaptation to local water temperature regimes.

Escapements to enhanced sites in Babine Lake typically exceed spawning requirements such that on average, more than a third of the Babine fence count is surplus produced by the Babine Lake Development Project. This occurs because the enhanced Fulton and Pinkut runs cannot be harvested fully in mixed-stock fisheries without over-harvesting less productive populations. In contrast, escapements to the co-migrating wild Morrison River run remain below escapement objectives and pre-enhancement levels. Recent escapements to other wild runs within Babine Lake, whose run timing is either earlier or later than the enhanced Fulton and Pinkut runs, are not statistically different from pre-enhancement levels.

Smolt production from the main basin of Babine Lake has increased dramatically as a result of enhancement. The enhanced Fulton and Pinkut runs now account for about 90 per cent of fry recruitment to the main basin. Even so, the available data suggest fry recruitment is still below levels required to yield maximum smolt biomass and maximum adult returns. In contrast, wild smolt production from Nilkitkwa Lake appears to have declined to less than a quarter of the level observed before enhanced returns were first exploited in 1970.

Increased smolt production from the Babine-Nilkitkwa lake system has led to dramatic increases in adult returns. However, the relationship between adult returns and smolt abundance is non-linear, perhaps reflecting competition among smolts. Even so, increased adult production could be expected from increased smolt production. The disparity between smolt-to-adult survival in even versus odd years noted by previous investigators is no longer evident.

Spawning escapements to other sockeye salmon populations in the Skeena watershed have been increasing steadily since the 1980s, presumably because of continuing efforts to harvest enhanced Babine sockeye salmon more selectively. However, escapements were generally poor in 1998 due to a combination of low marine survival and excessive harvest of the early-timing runs. Alaskan fisheries accounted for over half of the total exploitation rate of Skeena sockeye salmon in 1998 because the Canadian commercial fishery was greatly restricted.

Recent analyses of limnological and spawning ground survey data for Skeena lakes indicate that in most cases escapements are much too low to fully utilize lake rearing habitat and maximize smolt production. Minimum escapement goals or "limit reference points" are now being defined for the non-enhanced Skeena populations to ensure their conservation.

Fishery Management

Sockeye are an important food for First Nations people, and aboriginal fisheries have operated in the Skeena River for at least 5,000 years. Three First Nations in 17 aboriginal communities harvest Skeena sockeye: the Carrier-Sekani (Babine Lake area), Gitksan Wet'suwet'en (middle and upper Skeena) and Tsimshian (lower Skeena and adjacent ocean areas). Catches for food, social or ceremonial purposes have averaged 150,000 fish in recent years. Since 1993, new opportunities have also developed for First Nations to selectively harvest sockeye salmon considered surplus to Skeena spawning requirements. First Nations selectively harvested 500,000 surplus fish in 1996, but no surplus was available in 1997 and 1998.

The commercial Skeena River sockeye fishery began with the first cannery operations in 1877. Sockeye salmon were harvested predominantly by gill nets in the Skeena River until the 1930s, when powered vessels moved out to ocean fishing areas. In recent times, 200 to 1,000 gill net vessels have fished from the Skeena River mouth to outside fishing areas 70 km away, accounting for about 75 per cent of the harvest of Skeena sockeye. A seine fishery was introduced in the 1950s and grew rapidly through the next two decades. As many as 350 seine vessels have fished Skeena sockeye, predominantly in the outside fishing areas. Significant reductions in the gill net and seine fleets have recently been achieved through the Fisheries and Oceans Canada fleet restructuring initiative. The Canadian commercial catch of Skeena River sockeye has generally increased since 1970 to a record high of 3.7 million fish in 1996. However, fishing effort was severely restricted in 1997, 1998 and 1999 because of low sockeye salmon abundance. In 2000, there was an above average return of sockeye to the Skeena River and an average return of sockeye to the Nass River, which allowed for selective seine and gillnet full fleet fisheries. The management approach for 2001will be to conduct fisheries in a manner similar to previous years, with flexibility for more opportunities if in-season abundance is sufficient.

Many Skeena sockeye migrate homeward through southeastern Alaska, and a significant proportion of the total run is harvested in Alaskan gill net and seine fisheries. The Pacific Salmon Treaty, signed June 1998, limits catch in Alaskan fisheries directed at Skeena sockeye, but other interceptions occur as incidental harvests in Alaskan pink and chum salmon fisheries. Canadian management measures in 1999, enhanced by the Pacific Salmon Treaty, led to improved conservation of key sockeye, pink and chinook stocks. Interceptions of Skeena sockeye in Alaska were substantially less in 1999 and 2000 than previous levels.

Opportunities for recreational fishing on surplus enhanced sockeye salmon in the Skeena River have been provided in recent years. However, the recreational fishery remains extremely limited, with catches estimated to be only a few thousand fish.

The management of Skeena River sockeye involves a compromise between the dual objectives of maximizing catch from a single productive stock (enhanced Babine sockeye) and maintaining production from a diversity of less productive salmon populations. Accordingly, sockeye fisheries in Area 4 are managed to a moderate harvest rate of 42 per cent and timed to reduce the incidental catch of Skeena coho and steelhead, as well as the earlier migrating non-Babine sockeye. The aggregate escapement goal for Skeena sockeye is 900,000, but management has typically aimed to increase both escapement and exploitation rate when abundance is high.

A daily fishery model is used to evaluate alternative management scenarios and to estimate run size in-season. The gill net test fishery at Tyee in the lower Skeena River provides daily escapement indices that are calibrated against reliable escapement counts at the Babine River fence. A comprehensive monitoring program on the fishing grounds provides in-season estimates of commercial catch and effort. In-season forecasts of total abundance based on these data have proven to be relatively accurate by the second or third week of the fishery.

Skeena sockeye salmon abundance has increased dramatically since 1970 because of favourable marine survival and enhancement efforts at the Babine Lake Development Project. Over the same period, exploitation rates in the Canadian commercial fishery have actually declined because of increasingly restrictive management actions to protect less productive populations of steelhead, coho and chinook.

Outlook

Skeena River sockeye abundance in 1999 was a record low since enhancement began. Fortunately, smolt production has now returned to average levels. Skeena sockeye returns improved in 2000, and are expected to return to average levels in 2001.

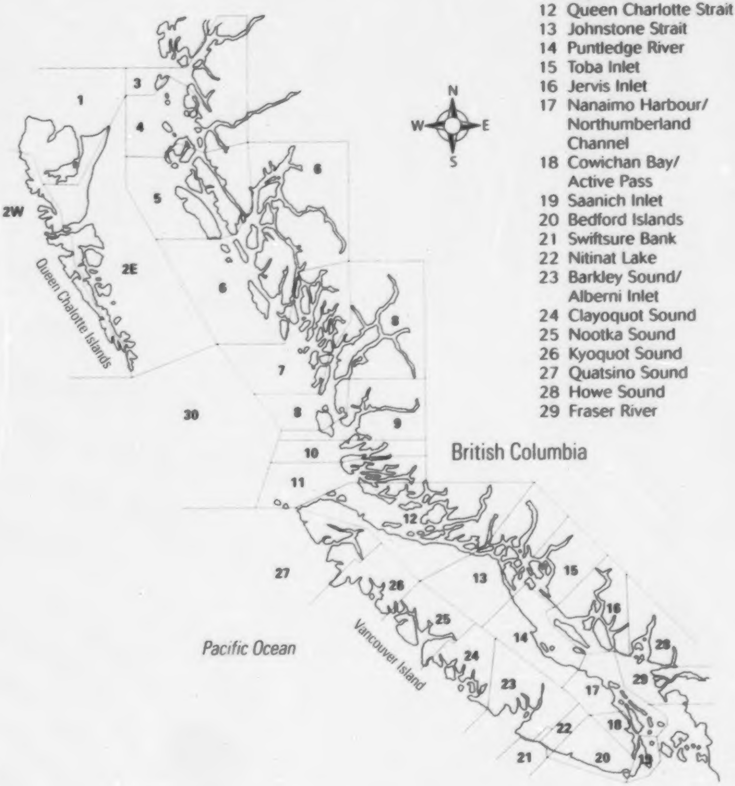
Groundfish

Management Areas

Northeastern Pacific Ocean

"The Pacific groundfish fishery is the largest fishery by weight on the Pacific Coast."

1 Masset Inlet
2 Queen Charlotte Island
3 Nass River
4 Skeena River
5 Hecate Strait
6 Kitimat River
7 Milbank & Mathieson Sounds
8 Burke Channel
9 Rivers Inlet
10 Cape Caution
11 Cape Scott
12 Queen Charlotte Strait
13 Johnstone Strait
14 Puntledge River
15 Toba Inlet
16 Jervis Inlet
17 Nanaimo Harbour/ Northumberland Channel
18 Cowichan Bay/ Active Pass
19 Saanich Inlet
20 Bedford Islands
21 Swiftsure Bank
22 Nitinat Lake
23 Barkley Sound/ Alberni Inlet
24 Clayoquot Sound
25 Nootka Sound
26 Kyoquot Sound
27 Quatsino Sound
28 Howe Sound
29 Fraser River



Groundfish

Groundfish is a broad term used to categorize demersal or benthic fish —fish that dwell at or near the bottom the ocean. Some of the species thought of as groundfish include rockfish, perch, thornyhead, skate, flatfish (flounder, sole), mackerel, and roundfish (greenlings, ling cod, Pacific cod, sablefish, sculpins, walleye pollock, Pacific hake).

Four groundfish fisheries occur in the Pacific region: trawl, halibut by hook and line, sablefish by trap and hook and line, rockfish and other species by hook and line. The Pacific groundfish fishery is the largest fishery by weight on the Pacific coast.

The groundfish trawl fishery in B.C. has existed since the 1940s. Trawl fishing by Canadians began in earnest in the 1960s; however, most fishing was conducted by foreign vessels operating off the west coast until the 200-mile limit was implemented by Canada in 1977.

Fisheries and Oceans Canada began to establish quotas and management measures to control the harvest of west coast groundfish stocks in 1979. These measures included license limitation, the establishment of Total Allowable Catches (TACs), and imposing species/areas closures, area/time closures and vessel trip limits on groundfish of commercial importance.

Since 1980, Fisheries and Oceans has consulted with industry through its Groundfish Trawl Advisory Committee (GTAC) to develop annual management plans. Through this consultative process, government and industry agreed on a plan in 1997 to implement an Individual Vessel Quota (IVQ) system for the commercial trawl groundfish fishery. The result is the most complex IVQ fishery in B.C., with fully transferable quotas set out for 25 different species in 55 different species area groups.

In 1999, the Groundfish Special Industry Committee (GSIC) conducted a full review of the Individual Vessel Quota/Groundfish Development Authority (IVQ/GDA) management plan, a commitment made as part of the 1997 IVQ program. GSIC is composed of representatives from the west coast trawl industry, coastal communities and officials from the B.C. provincial government and Fisheries and Oceans Canada. The comprehensive review process consisted of meetings and public consultation sessions involving committee members, fishers, license holders and processors, crew members, shore workers, and the general public dependent on, or affected by, this fishery.

The committee used information gained through this consultative process to develop recommendations for changes to the IVQ/GDA program for the 2000-01 fishing season and beyond. These recommendations are contained in the report "Review of the Groundfish Trawl Individual Vessel Quota/Groundfish Development Authority Plan – Final Report and Recommendations", and were subsequently approved by the Minister of Fisheries and Oceans and B.C.'s Minister of Fisheries.

Overall, the Groundfish Special Industry Committee found the IVQ/GDA program provided a very stable management regime for the industry to operate under while meeting Fisheries and Ocean's objectives for a properly controlled and monitored fishery, with harvest levels remaining within established TACs. The program has entrenched into the fishery personal accountability (that is, individual fishers are responsible for his/her fishing activity), and has fostered a new level of communication and cooperation in the industry. This has led to sharing knowledge of innovative, avoidance and selective fishing techniques, and increased the value of the fishery through better marketing practices.

The review process was significant as it lead to industry standards as well as long-term direction for this valuable fishery. The individual vessel quota program also resulted in a more sustainable, more flexible and safer fishery, with improved financial viability for the industry. In addition, the program involves vessel owners in a more cooperative approach towards the management of the resource.

The 1999 groundfish trawl fleet was composed of 142 licensed vessels, of which approximately 88 recorded landings. It is the largest fishery by volume on Canada's west coast, with annual landings of approximately 140,000 tonnes, worth an estimated value of $60-65 million.

In this complex fishery, 77 species of fish are landed and 27 different groundfish stocks are assessed and subject to annual allocations in six different management areas. The groundfish fishery contributes significantly to the B.C. fishing industry by providing a consistent, year-round supply of groundfish, as well as year-round employment in both the processing and harvesting sectors.

The industry and Fisheries and Oceans Canada are committed to working together to develop an ecosystem management regime to promote responsible fishing practices. Since 1996, the groundfish trawl net fleet must have a fisheries observer onboard while fishing to ensure that all catch, including discards, are monitored. This allows Fisheries and Oceans managers to accurately determine catch and bycatch levels, thereby strengthening its stock assessment capability. When compared to other trawl fisheries around the world, Canada has one of the most advanced and scientifically defensible management systems.

Similarly, in 1999, Fisheries and Oceans Canada introduced at-sea observers in the halibut fishery and, in 2001, expanded this requirement to other groundfish hook and line fisheries. Bycatch in the hook and line industry has been a key issue that Fisheries and Oceans has addressed and made progress on with the advisory group. The total mortality of halibut bycatch by trawl is approximately 250,000 pounds.

Overall, the management of groundfish fisheries on Canada's west coast is based on the best biological information available, and conservative approaches to management are applied when establishing the annual management plan.

Pacific Cod

Background

Pacific cod (*Gadus macrocephalus*) are opportunistic feeders preying on invertebrates (amphipods, euphausiids, shrimp and crabs) and fish (herring, sand lance and flatfish). The species is widely distributed in the coastal North Pacific, from the Bering Sea south to Santa Monica, California in the east and the Sea of Japan in the west. Four stocks of Pacific cod are defined for management purposes on Canada's west coast: Strait of Georgia, west coast of Vancouver Island, Queen Charlotte Sound, and Hecate Strait. This report, however, considers only the Hecate Strait stock.

Tagging studies indicate that there is very little movement of cod among areas. The depth distribution of landings indicates there is a seasonal migration between shallow waters in spring and summer and deeper waters in fall and winter. Spawning occurs mainly in February and March. Although it is difficult to age Pacific cod, their growth rates are believed to be relatively fast, reaching about 30 cm in the first year of life and sexual maturity by two to three years of age.

Stock projections conducted through to 2002 suggest that the spawning stock biomass will continue to decrease through 2001 with a small probability of increase in 2002.

Fishery Management

Pacific cod in Hecate Strait are fished mainly with trawls. The species is a significant component of the multi-species groundfish fishery in the area. Annual yields have ranged from a high of 8,870 tonnes in 1987 to a low of 403 tonnes in 1996.

The trawl fishery has undergone a number of significant changes in recent years that may influence the quality and comparability of data collected from the fisheries. Prior to 1992, the total catch of Pacific cod was unrestricted and the main management measures were area/season closures. Total allowable catches were introduced in the Hecate Strait area in 1992. Trip limits were also introduced in the same year and these decreased steadily until 1995. For the 1996 season, trawl catches were limited to by-catch only because of stock concerns. An individual vessel quota system was introduced for the B.C. trawl fishery in 1996, and the fishing season was changed from a calendar year to April–March.

A voluntary 140-mm minimum cod end mesh size was suggested in the 1991

Pacific Groundfish Trawl Management Plan for the Hecate Strait area, compared with a coast-wide regulation for 76 mm. The 140-mm minimum was legislated for Hecate Strait in 1995.

Reconstructions of the Hecate Strait Pacific cod stock were conducted using a catch-at-length model, as in previous assessments. Recently, data was included from the multi-species Hecate Strait survey. While Pacific cod abundance indices from this survey are not precise, the survey has been conducted in a consistent manner since 1984 and should provide information on the general trends in relative abundance.

Stock analyses were conducted under two different assumptions. The first was that selectivity for 60-cm fish was constant among commercial fisheries (time periods and fishing quarters). The other assumes that selectivity for 70-cm fish was constant among the fisheries. Both analyses suggest that stock abundance remains near historic low levels, recruitment of the last nine year-classes is below the median level, and the 1998 year-class is the smallest ever. The last result is largely dependent on the length structure observed in the 1998 Hecate Strait survey.

Outlook

The assessment indicates that stock biomass was at historically low levels in 1994–96, with a slight increase in the following two years. Recruitment estimates are low with the last nine year-classes being below the long-term average. This is the longest run of below average year-classes in the time series, which goes back to 1956.

Sablefish

Background

Sablefish (*Anoplopoma fimbria*), also known as black cod, inhabit shelf and slope water to depths greater than 1,500 metres from central Baja California to Japan and the Bering Sea. Although genetic studies suggest a single population throughout their range, movement of adults is limited enough to allow assessment and management on a smaller scale. Recruitment and growth patterns indicate the presence of two stocks in Canada's west coast waters.

The species spawns from January to March along the continental shelf at depths greater than 1,000 metres. Larval sablefish are found in surface waters over the shelf and slope in April and May. Juveniles migrate inshore during the following six months and rear in nearshore and shelf habitats until the age of two to five, when they migrate offshore and into the fishery. Juveniles are highly migratory, traveling from nursery areas in Hecate Strait to Alaska. Growth is rapid, with mature females reaching an average length of 55 cm in three to five years. The oldest fish aged to date is 113 years and has a length of 90 cm. Age, growth and maturity vary considerably among areas and depths. Recruitment rates also vary, with the strongest years occurring when environmental conditions are favourable.

Stock assessments use a new integrated catch-at-age mark-recapture model to estimate the current stock size and reconstruct the history of the stock. Data sources include catch from longline, trawl and trap fisheries, catch-at-age from the trap fishery between 1980 and 1995, and release-recapture tagging programs conducted from 1979–82 and 1991–97. Current stock size is well determined, but there is uncertainty in stock reconstruction due to differing results of two tagging data sets and the selectivity of males. Evidence from recent research and anecdotal reports suggest that recruitment has improved in recent years.

The available age compositions and larval surveys provide evidence of an above-average year class around 1990. Studies of juvenile by-catch in the trawl fishery and anecdotal reports from sablefish fishers indicate that the 1997 class may be above average. The observations are consistent with recent indications of a shift to more favourable environmental conditions linked to climate change.

Fishery Management

Sablefish have a long history of exploitation, with the first recorded landings in 1913. Foreign fishing was conducted from 1961–81 and phased out after the declaration of the 200-mile fishery conservation zone in 1977.

The domestic fishery uses longline Korean traps, landing modest amounts using longline-hooks and trawl nets. The longline fisheries are deepwater, targeting depths of between 300 and 1,000 metres. Sablefish longline fishers are regulated under a "K" tab licence and can employ hooks or traps. This fishery has operated under an Individual Transferable Quota system since 1990. All research, management and enforcement costs are recovered from industry. The trawl fishery is allocated approximately 8 per cent of the available quota.

Sablefish continues to be one of B.C.'s most important fisheries. The 4,087 tonnes landed in 1997 were worth an estimated $25 million. The majority of the product is headed and gutted using a "J" cut, frozen at sea and exported to Japan.

Outlook

Fisheries and Oceans Canada conducted deterministic stock projections for the years 1998 through 2006 for three fixed levels of recruitment and three fixed levels of fishing mortality. The recruitment levels were 0.6, 1.0 and 1.4 times the mean of the 1966–94 estimates. The region-specific mortality levels were 0.8, 1.0 and 1.2 times the 1997 estimates. In all but the high recruitment scenarios the biomass is stable or declining slightly.

Rock Sole

Background

Three species of what are popularly known as rock sole can be found in the North Pacific, but only two are found off Canada's west coast, *Lepidopsetta bilineata* and *Lepidopsetta petraborealis*. Of the two, the latter, a southern species, is most common. The range of *L. bilineata* extends from Baja California to the southeastern Bering Sea, while *L. petraborealis* can be found from Puget Sound to the southern Sea of Okhotsk. Four discrete populations have been identified off the B.C. coast – two in Queen Charlotte Sound (Areas 5A–B) and two in Hecate Strait (Areas 5C–D).

Life histories are similar among the species. They live as long as 21 years and recruit to the commercial fishery at about four years of age. They have evolved to spawn annually over the course of their lifetime. Males begin to spawn at three years of age, while females begin to spawn at age four.

Directed fishing for rock sole takes place at trawling grounds in Queen Charlotte Sound and Hecate Strait. The commercial fishery was unregulated prior to 1980, but since that time monthly vessel trip quotas have been imposed.

Since the mid-1980s, a biannual trawl survey has been conducted in Hecate Strait to assess the abundance of rock sole and other groundfish species in the region. Cyclical abundance levels are mainly a response to variability in the ocean environment. Results indicate there was an overall increase in the abundance of rock sole between 1984 and 1991, eventually reaching a 50-year peak. Abundance has declined since that time due to a decline in recruitment, and warmer ocean temperatures during the recent El Niño event have led to lower survival of young fish. In 1998, rock sole abundance was near the long-term average for the last 50 years, but declining.

Fishery Management

Landings of rock sole from the commercial fishery increased from 100 tonnes in the mid-1940s to more than 3,000 tonnes in the early 1990s. The average annual landings of rock sole from 1945–98 was approximately 1,500 tonnes. Rock sole are caught in a directed trawl fishery and as a bycatch of the Pacific cod fishery. The rock sole fishery involved both Canadian and U.S. vessels until 1977, when Canada declared extended jurisdiction over its offshore resources. Subsequently, the fishery has been exclusively Canadian.

Outlook

Annual landings of rock sole have fluctuated regularly over time. Low recruitment rates in recent years have led to cuts in quotas, and as a result, fishing effort has also fallen. Rock sole abundance is not expected to increase significantly in the near future because of unfavourable conditions in the ocean environment. The total allowable catch of rock sole will remain relatively low to protect these stocks until abundance increases.

Management is based on a yield corresponding to a fishing mortality reference point of F0.1. The stock should be able to maintain its spawning biomass with fishing at this rate, which will enhance the probability of increased recruitment. In addition, the establishment of a mesh regulation in 1995 will help minimize mortality of juveniles. It will also have a positive effect on recruitment for the stock in the long term.

Dover Sole

Background

Dover sole (*Microstomus pacificus*) ranges from Baja California to the Bering Sea. It is one of four flatfish species caught in the commercial trawl fishery off Canada's west coast, which is nearly the northern limit of this species' commercial abundance.

Two discrete populations have been identified in coastal B.C. waters. The southern population occupies the area off the west coast of Vancouver Island (Areas 3C–D), while the northern population occupies Queen Charlotte Sound, Hecate Strait and the west coast of the Queen Charlotte Islands (Areas 5A–E).

Dover sole can live for 45 years and are first available to the commercial fishery at about six to seven years of age. They spawn annually in winter in deepwater between 800 and 1,000 metres. Males begin to spawn at four years of age, while females begin to spawn at age five.

Directed fishing for Dover sole takes place at fishing grounds throughout the B.C. coast with the exception of the Strait of Georgia. The fishery was regulated using area quotas until 1996, when managers introduced individual vessel quotas.

The fishery for Dover sole occurs in deepwater (400–1,000 metres) off the west coasts of Vancouver Island and the Queen Charlotte Islands during late fall and winter, and at depths of 100–200 metres in Hecate Strait, Queen Charlotte Sound and off the west coast of Vancouver Island during spring and summer. The winter fishery occurs predominately on spawning concentrations. The northern fishery was initiated in the 1970s, while the west coast of Vancouver Island fishery was started in the late 1980s.

Fishery Management

From 1970–87, landings of Dover sole ranged between 500 and 1,000 tonnes, which came almost exclusively from grounds inhabited by the northern stock. Landings increased significantly between 1988–98 with the development of the deepwater trawl fishery off the west coast of Vancouver Island.

In recent years both the northern and southern stocks have been exploited near the maximum sustainable yield. Dover sole abundance has declined recently, possibly due to the high exploitation rates of the late 1980s and early 1990s. In 1996 and 1997, individual vessel quotas were reduced to avert declines in abundance, but in 1998 landings increased due to an expansion of the fishing area. Stock abundance in 1999 and 2000 for Dover sole was average to high and the coastwide total allowable catch (TAC) for the 2000–2001 fishing season is 3,073 tonnes. It appears that both populations have stabilized as a result of applying quotas in 1996.

Management of the fishery in recent years has been based on the target fishing mortality reference point of F0.1. The individual vessel quotas and fishery observer program established by fishery management have helped to control the harvest of these stocks. In addition, the observer data provide more comprehensive information that can be used for stock assessment, especially for the developing fishery on B.C.'s south coast.

Outlook

Dover sole is moderately long-lived and has a relatively slow turnover rate. The abundance of both populations should stabilize with the lower quotas applied in recent years.

English Sole

Background

English sole (*Parophrys vetulus*) is one of four important flatfish caught in the commercial trawl fishery off Canada's west coast. While its range extends from Baja California to the Bering Sea, B.C. is the northern limit of commercial abundance for the species. The largest discrete stock in B.C. coastal waters is found in Hecate Strait (Areas 5C–D).

English sole live as long as 21 years and recruit to the commercial fishery at about four years of age. They spawn annually, males beginning at three years of age and females at four years. Abundance has fluctuated cyclically over the last 40 years, mainly because of variability in the ocean environment. English sole abundance increased steadily between 1962 and 1993. Since then, the stock has shrunk in size primarily due to a decline in the proportion of young fish recruiting to the population.

Directed fishing for English sole takes place primarily on fishing grounds in Hecate Strait, and to a lesser extent in Queen Charlotte Sound and off the west coast of Vancouver Island. The fishery for English sole was unregulated prior to 1990, when managers imposed annual quotas. Individual vessel quotas were applied in 1996. The biomass of the stock underwent a prolonged decline between the early 1950s and mid-1960s, but it recovered by the mid-1970s. The biomass was above the 50-year average in 1997.

Fishery Management

Annual landings of English sole by the commercial trawl fishery have fluctuated between 100 and 2,600 tonnes. The average annual landing of English sole between 1944 and 1997 was about 800 tonnes. English sole are caught in a directed trawl fishery and are a component of the bycatch in the trawl fishery for rock sole and Pacific cod.

The fishery for English sole involved both Canadian and U.S. vessels until 1977, when Canada declared extended jurisdiction over its offshore resources. Since then, the fishery has been exclusively Canadian. Landings of English sole from Hecate Strait have been declining in recent years as quotas were lowered to accommodate a decline in stock abundance.

Research trawl surveys have been conducted in Hecate Strait to assess the abundance of English sole and other groundfish species over the last 15 years. The survey catch-rate index (in terms of catch per unit of effort) for English sole increased significantly in the late 1980s, but declined between the early and mid-1990s.

Outlook

Management is based on a fixed exploitation rate corresponding to a fishing mortality reference point of F0.1. Such an exploitation rate will allow the stock to maintain its spawning stock biomass and ensure a recruitment rate that will sustain the stock in the long term. Abundance levels have been declining in recent years along with fishing effort due to lower allowable catches. No change in his trend is expected in the near future because of unfavourable ocean conditions. Allowable catches of this species will be maintained at the current level until changes in recruitment and abundance are evident.

Petrale Sole

Background

The Petrale sole (*Eopsetta jordani*) is a flatfish caught in the commercial trawl fishery off Canada's west coast. The range of the species extends from Baja California to the Bering Sea, with B.C. near the northern limit of commercial abundance.

Two discrete populations have been identified in B.C. coastal waters, one off the southwest coast of Vancouver Island (Area 3C), and another off northwest Vancouver Island (Area 3D), Queen Charlotte Sound (Areas 5A–B) and Hecate Strait (Areas 5C–D).

Petrale sole can live as long as 30 years, becoming available to the commercial fishery at about four or five years of age and spawning annually in winter. Adults occupy depths of 80–500 metres off the west coast of Vancouver Island. Males begin to spawn at three or four years of age, while females begin at four or five years.

Fishery Management

Directed fishing for Petrale sole is now prohibited because of a long-term decline in abundance of the species. The fishery developed rapidly in the mid-1950s following the discovery of large concentrations of spawning Petrale sole off the west coast of Vancouver Island. Since Canada's declaration of extended offshore jurisdiction in 1977, the fishery has been exclusively Canadian. No directed fishery on Petrale sole has been permitted since 1995, although the species is caught incidentally by other fisheries in all areas of the coast.

Annual landings from the commercial fishery for Petrale sole in B.C. peaked at 4,800 metric tonnes in 1948. However, they declined significantly after the mid-1960s. Vessel trip quotas were established in the early 1990s to limit the fishery on the species because of the decline.

Landings of Petrale sole at the present time are very low. This is partially due to the effect of a non-directed fishery. Biological data for 1980–96 show a prolonged decline in the proportion of young fish entering the population. Although environment plays a strong role in regulating abundance for the species, scientists are concerned that the decline may be linked to low spawning stock biomass. They have recommended a non-directed fishery until a more detailed analysis can be conducted.

Outlook

Recent El Niño events were expected to have a positive effect on the abundance of the Petrale sole. When this did not occur, remedial measures were taken in hopes that the stocks will eventually support a directed fishery once again. The regulatory measures imposed by managers have eliminated the fishery on spawning concentrations and should allow abundance to increase. In addition, an observer program initiated in 1996 has allowed more accurate monitoring of the catch and full compliance with the non-directed fishery regulations. This program could also be used for the collection of biological data to monitor and assess stocks in the future.

ROCKFISH

In the waters off Canada's west coast there are more than 36 known species of rockfish belonging to the family *Scorpaenidae*, which in turn is represented by 34 species of the genus *Sebastes* and two of the genus *Sebastolobus*.

Although the geographic range is different for each species, rockfish may be found in the North Pacific Ocean from southern California to Kyushu Island, Japan and in the Atlantic Ocean. The majority of the species inhabit the continental shelf and upper slope regions, and consequently are sometimes described as "nearshore", "shelf" or "slope" rockfish.

Rockfish are distinguished by their stout, heavy build, large, broad heads which usually bear spines and strong ridges; and heavily-spined fins. The colour patterns vary greatly among species and range from black and drab green through brilliant orange and crimson, with some accented by wide red or black vertical stripes. They are opportunistic feeders, eating a variety of foods, including herring, sand lance, crabs, shrimp and euphausiids.

Pacific Ocean Perch

Background

Pacific ocean perch (*Sebastes alutus*) is the most important rockfish species in the B.C. trawl fishery in terms of total landed catch. This species occupies depths from 40–640 metres, and ranges from southern California to the Bering Sea as far southwest as the Kurile Islands. It is generally captured by trawl gear over cobble substrate but may prefer rocky, high relief substrate.

Pacific ocean perch reach a maximum length of about 50 cm and a maximum age of close to 100 years. About half of the females mature by the age of eight years at a length of approximately 35 cm, while 50 per cent of males reach sexual maturity at six to eight years and a length of about 34 cm. Each female produces between 90,000 and 510,000 eggs. Fertilization is internal and the eggs, which obtain at least some of their nutrition from the parent during development, remain within the ovary until larval extrusion. Young are born in March off Vancouver Island and somewhat later further north in Queen Charlotte Sound. Juveniles may remain pelagic until the second or third year of life and are fully recruited to the fishery by age 16.

Fishery Management

A trawl fishery for Pacific ocean perch and other rockfish has existed on Canada's west coast since the 1940s. However, Canadian catches were relatively minor before the mid-1970s. A foreign fishery was active coastwide between 1956 and 1982, with the largest catches landed by Soviet and Japanese fleets between 1965 and 1970. In 1971, Canada imposed a fishery closure east of a line from the southern tip of Moresby Island to the northern tip of Vancouver Island. This closure reduced, but did not entirely limit, further foreign fishing within Queen Charlotte Sound. The establishment of Canadian extended jurisdiction to the 200-mile limit in 1977 halted directed fishing on rockfish by Japanese and Soviet vessels, although incidental catches are still taken in the joint venture hake fishery. The U.S. trawl fleet continued to fish for rockfish in Canadian waters until 1982.

The Canadian trawl fishery began to target Pacific ocean perch around 1980, and since then the average annual catch has been 5,680 tonnes (1980–96). The major fishery occurs in Queen Charlotte Sound in three gullies: Goose Island, Mitchell's and

Moresby. Goose Island Gully and, to a lesser extent, Mitchell's Gully were the main sites of the historical fishery, while Moresby Gully only became a target area in 1980. Large landings were also reported from the Langara Spit area off the northwest coast of Graham Island from 1983–90 as a result of an open-fishing experiment.

Collection of catch statistics for Pacific ocean perch and other rockfish began in 1954 with the introduction of a voluntary trawl logbook program. In the early years, statistics were confounded by the practice of reporting the catch of several similar species under one category such as "ocean perch" or "red rockfish". By the late 1970s, as management efforts grew more restrictive, fishermen began to report an increasing number of species landed. This increase may reflect an effort to utilize some less restricted species, but misreporting may have also occurred. A mandatory dockside monitoring program implemented for the majority of the trawl fishery in 1994 has improved species identification and cut down on misreporting. In 1996, a mandatory on-board observer program was introduced that was applied to the entire trawl fleet. The observer program provides detailed and timely catch information on a tow-by-tow basis and is necessary for management and stock assessment.

Stock assessments of Pacific ocean perch involve five geographical designations: the west coast of Vancouver Island, Goose Island Gully and Mitchell's Gully of Queen Charlotte Sound, Moresby Gully, the west coast of the Queen Charlotte Island, and North of 54° (Langara Spit).

The west coast of Vancouver Island was targeted by the foreign fishery in the mid-1960s, with large removals of Pacific ocean perch. Several analyses in the late 1970s indicated that stock biomass was substantially lower than the mid-1960 level. To gather more information on biomass levels and potential yield, an overfishing experiment, with a quota of 300–500 tonnes, was conducted from 1980–84. Upon completion of the experiment, a research survey in 1985 estimated Pacific ocean perch biomass at 1,900 tonnes, a reduction of 51 per cent from the 1979 estimate. In addition, the survey catch per unit effort for all rockfish fell by 68 per cent between 1979 and 1985. More recently, U.S. assessments have projected a continued low biomass of Pacific ocean perch in U.S. waters.

Based on age-structure data collected during a 1996 survey, the 1984 year-class dominates the population. This year-class would not have been detected in the 1985 survey. The 1976 year-class, although still present in the 1996 samples, appears less dominant than in comparable samples from Goose Island and Moresby gullies, and from Langara Spit. The absence of strong year-classes after 1984 is consistent with other Pacific ocean perch stocks in B.C.

Without any incoming strong year-classes, the 1984 year-class continues to support the fishery, and biomass is declining. Between 1985 and 1996, the reported average annual catch of 495 tonnes led to high total mortality rates. The 1995 survey biomass estimate for Goose Island and Mitchell's gullies is 14 times greater than the 1996 estimate for the west coast of Vancouver Island.

A 1996 survey of the west coast of Vancouver Island indicated that the estimated biomass of Pacific ocean perch may be close to 2,000 tonnes, similar to an estimate produced from a survey done in 1985. Thus, there is some indication that population numbers have been relatively stable off the southwest coast of Vancouver Island since 1985.

Limited information is available to assess the status of Pacific ocean perch off the northwest coast of Vancouver Island. A large foreign fishery was active there in the mid-1960s but did not take significant quantities. Reported catch from this area has been declining steadily since 1989 while effort has remained constant. This decline suggests a continuing low biomass for this area.

In Goose Island and Mitchell's gullies of Queen Charlotte Sound, regular trawl surveys to estimate Pacific ocean perch biomass were conducted between 1965 and 1984. After a 10-year gap, biomass surveys were again conducted in 1994 and by two vessels simultaneously in 1995. Relative biomass estimates from the 1995 surveys ranged from 18,179 to 31,369 tonnes. These estimates are the highest recorded since the surveys began in 1965. However, comparison of results from the 1995 and earlier surveys is complicated by differences in survey design. In particular, coverage of the survey area was more comprehensive in 1995 than in earlier surveys. The survey series since 1965 forms the basis of the most recent catch-age analysis of Goose Island Gully. This analysis indicates that, by 1977, the foreign fishery reduced the Goose Island Gully stock of Pacific ocean perch to about one-third of the 1965 exploitable biomass.

Between 1977 and 1984, exploitable biomass remained relatively constant. By 1995, it increased to more than half of the 1965 level as a result of above-average recruitment and low fishing mortality rates.

There have been no biomass surveys in Moresby Gully since 1981, and there is little independent fishery information available to assess the status of Pacific ocean perch in this area. Nevertheless, given the increase seen in Goose Island Gully, biomass in Moresby Gully may also have increased since the early 1980s. Moresby Gully was not targeted by the foreign fishery and the 1976, 1980, and 1984 year-classes were well-represented in an age-structured analysis performed in 1995.

Trawl surveys have been conducted sporadically off the west coast of the Queen Charlotte Islands since 1966. The August 1997 survey estimated Pacific ocean perch biomass at approximately 13,400 tonnes. A relatively strong 1990 cohort was identified.

An over-fishing experiment took place in the North of 54° (Langara Spit) region off the northwest coast of Queen Charlotte Island between 1983 and 1990. This was followed by a period of closure between 1991 and 1996. Surveys to monitor the experiment were conducted in 1993, 1996 and 1997. The 1996 and 1997 surveys suggest a modest rebuilding of the stock since 1993. Recruitment of recent cohorts appears lower than during the early to mid-1980s over most of the Langara Spit region, with the exception of one area showing a relatively strong 1990 year-class. The absence of significant recruitment of cohorts from the late 1980s suggests that increases in biomass over the next few years will be limited primarily to contributions from existing cohorts.

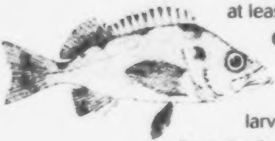
Outlook

Many fishermen report an increasing abundance of Pacific ocean perch recently. However, these perceived increases are likely due to the growth of individuals rather than an increase in recruitment. There has been no significant increase in recruitment over the past several years. Stocks are expected to decline slowly from current levels of abundance until recruitment increases.

Yellowmouth Rockfish

Background

The yellowmouth rockfish (*Sebastes reedi*) is the second most abundant slope rockfish in terms of catch along Canada's west coast, after Pacific ocean perch (*Sebastes alutus*). These two species share many physical features and, prior to the mid-1970s, both were often classified as "red rockfish" or "ocean perch" in catch records.



This species ranges from the Gulf of Alaska to northern California and occurs at depths of 100–430 metres. Adults reach a maximum age of at least 70 and possibly 100 years, and a maximum length of about 60 cm. Both males and females reach 50 per cent maturity at approximately 38 cm in length. Females spawn primarily in April and May. Fertilized eggs remain within the ovary until larval extrusion and may obtain at least some of their nutrition from the female parent during development.

Fishery Management

A trawl fishery for yellowmouth rockfish and other slope rockfish has existed in B.C. since the 1940s. A foreign fishery was active coastwide between 1956 and 1982 with the largest catches landed by Soviet and Japanese fleets between 1965 and 1970. In the early years of the Canadian trawl fishery, statistics were confounded by the practice of reporting the catch of several similar species under one category. However, reporting has improved since the late 1970s to the extent that most yellowmouth rockfish catch is now properly identified.

Yellowmouth rockfish are captured primarily by bottom and mid-water trawl gear with the largest catches taken from Goose Island and Mitchell's gullies in Queen Charlotte Sound. Coastwide catches have increased steadily in the past several years, rising from approximately 1,200 tonnes in 1994 to 2,200 tonnes in 1997. The B.C. hook-and-line catch of yellowmouth is significant, but much less than the trawl catch, and has dropped from 16 tonnes in 1995 to three tonnes in 1997.

In the past, quotas for yellowmouth rockfish have been set relative to the Pacific ocean perch quotas, based on observed relative abundance from biomass surveys. However, these surveys have been directed at Pacific ocean perch and have employed bottom trawl gear only. Nevertheless, based on relative increases observed in these surveys and recent catch history, yellowmouth rockfish stocks may be at an average level of abundance.

Outlook

Limited age data gathered between 1990 and 1992 suggest that 1982 was the last year that a significant recruitment event occurred in yellowmouth rockfish stocks on Canada's west coast. Therefore, abundance is expected to decline until the next major recruitment takes place. Such an event would likely not become evident in age data from the fishery until fish reach the age of seven.

Yellowtail Rockfish

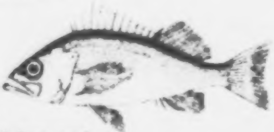
Background

Yellowtail rockfish (*Sebastes flavidus*) is an important component of the rockfish catch in the commercial trawl fishery off Canada's west coast. One of over 36 species of rockfish found in B.C. waters, the Yellowtail rockfish ranges from southern California to the Gulf of Alaska. The principal area of commercial abundance is northern California to northern B.C.

Recruiting to the fishery begins at age five, and individuals can live more than 50 years. Mating takes place in mid-fall; free-swimming larvae are released in late winter or early spring. Males and females mature between the ages of 5 and 14 years, to a maximum size of 3–4 kg.

In B.C., yellowtail rockfish are treated as two stocks. The southern or "Boundary" stock is shared with the U.S. fishery and is assumed to extend from northern Washington to central Vancouver Island. The "Coastal" stock includes the area from central Vancouver Island to the Alaska border. Although preliminary genetic research provides a basis for separating northern Washington stocks from the more southern populations, stock boundaries themselves are poorly understood. Limited tagging work has indicated that at least a few individuals travel long distances, from southeast Alaska to central B.C., and from central B.C. to the central Washington coast.

In both Boundary and Coastal yellowtail stocks, population biomass appears to be decreasing and recruitment appears to have been poor during the 1990s. Assessments are imprecise, however, due to the lack of an appropriate index of abundance.



Fishery Management

Yellowtail rockfish are caught in a directed trawl fishery. They are also a bycatch of fisheries for hake, other rockfish and ling cod (*Ophiodon elongatus*). Commercial catches are made at depths of 100–200 metres using bottom and mid-water trawls. The hook-and-line fishery produces minor landings.

Off the southwest coast of Vancouver Island, U.S. and Canadian trawlers jointly exploit, in their respective zones, one stock of yellowtail rockfish. A large proportion of landings are incidental to the mid-water fishery conducted by both nations for hake; a small percentage is captured as bycatch in the U.S. shrimp trawl fishery.

Large-scale surveys of yellowtail rockfish are impractical, partly because of the behaviour of this species, which lives in both near- and off-bottom habitats. Neither swept-area nor acoustic estimation alone is appropriate. However, stock abundance indices for both Coastal and Boundary stocks of yellowtail rockfish stock are declining. Current exploitable biomass is well below 50 per cent and possibly as low as 25 per cent for the Boundary stock, and may be similar for the Coastal stock. If recruitment continues to be poor, there is a high risk of continued decline in biomass. It is not known when the current period of poor recruitment will end.

Reliable landings data for the commercial yellowtail fishery start in the late 1960s. Landings increased from approximately 1,000 tonnes in the 1960s to more than 5,000 tonnes in the early 1990s. Total annual Canadian landings for yellowtail rockfish have recently averaged about 5,000 tonnes, with most landings coming from Queen Charlotte Sound and the south and central coast of Vancouver Island.

Since 1980, fishery managers have used a combination of coastwide or area quotas in combination with trip limits. Annual quotas are usually filled. Individual vessel quotas have been in place since 1997.

The Coastal stock quota was reduced in 1998 from 4,514 to 3,459 tonnes. The quota for Canadian landings of the Boundary stock was raised from 719 to 1,005 tonnes in 1998, which includes bycatch from the offshore hake fishery. Landings from the rest of the coast, central Vancouver Island and north, are assumed to come from the Coastal stock. Since 1967, annual landings have averaged 2,800 tonnes, although the figures for the last decade show landings have increased to an average of 4,000 tonnes.

Outlook

The southern Boundary stock appears to be declining in abundance, principally due to poor recruitment in recent years. The assessment is based on biomass estimates from U.S. triennial trawl surveys, hake bycatch indices from the Canadian joint-venture fishery, and catch-at-age information. Effective quota recommendations from both nations were lowered for 1997 and remained low for 1999. Combined landings were only 1,517 tonnes in 1997. Stock abundance appears to be about 25 per cent of the pre-fished biomass.

Although considerably fewer data are available for the Coastal stock, it also appears to be declining in abundance after a sustained period of poor recruitment. It was also assessed using catch-at-age analysis, but results are not conclusive. The recommended yield range was lowered from 2,750–5,100 tonnes to 2,000–4,025 tonnes for 1998 and 1999 due to the progressive reduction in average age during the 1990s.

Canary Rockfish

Background

Canary rockfish (*Sebastes pinniger*) live close to the ocean bottom and appear to prefer areas of high relief near the edge of the continental shelf, where they feed on small fish and euphausiids. While males live up to 60 years of age, females rarely live to 35 years. They are often confused with yelloweye rockfish (*S. ruberrimus*) because of the brilliant gold colour on their sides.

This species is an important component of the rockfish catch in the commercial trawl fishery off Canada's west coast. Adults are captured at a depth of 50–375 metres, although juveniles can be seen in much shallower waters. The principal depth of capture is 100–200 metres.

Canary rockfish begin recruiting to the fishery at age six and live to up to 60 years. Mating takes place in mid-fall and free-swimming larvae are released in late winter or early spring. Males and females mature between the ages of five and 18, and grow to about 55–60 cm in length.

Current assessment research is limited to the collection of basic landings data as well as size and age composition information. Surveys are problematic, given the relatively small size of the stocks, the propensity for the species to live too close to the bottom for acoustic estimation, and its preference for areas where bottom-trawl assessments cannot be performed.

Stock status is poorly understood due to the lack of biological samples and absence of an abundance index. The limited age composition data do not indicate, for either stock, a significant reduction in frequency of older fish and therefore do not imply high exploitation. However, this could also be the result of poor recruitment in the 1990s.

Fishery Management

The fishery began in the early 1960s, although the first recorded landings for the species were not made until 1967. The Canadian fishery did not begin until the mid-1970s. Since then, annual landings have averaged approximately 1,000 tonnes, but only 750 tonnes over the last five years. Most landings come from a bottom-trawl fishery on the central coast of Vancouver Island and Queen Charlotte Sound. The principal area of commercial abundance is the coastal area of northern California to central B.C. Bottom trawling is the principal fishing technique, but there is also a growing hook-and-line catch of canary rockfish. Between 60 and 70 per cent of the landings is taken from the southern stock off the west coast of Vancouver Island.

Stock assessment and management treat canary rockfish in B.C. waters as two coastal stocks – one off the west coast of Vancouver Island and another in Queen Charlotte Sound – although actual stock boundaries are unknown. Since 1993, fishery managers have used a coastwide quota in combination with trip limits. Annual quotas are not always filled, and individual vessel quotas have been in place since 1997.

Age composition in the catches tends to indicate that fishery exploitation has had a significant impact but there are no convincing signs of over-exploitation. Landings in 1998 from the west coast of Vancouver Island and Queen Charlotte Sound were both lower than the historical average and the 1997 total allowable catch. It is not known, however, whether the failure to reach the total allowable catch was the result of the introduction of individual vessel quotas or reduced availability. Stock abundance of Canary rockfish remained low to average in 1999 and 2000. Commercial harvest recommendations for the West Coast of Vancouver Island (3 C/D) increased in 2000 whereas the recommended harvest rate decreased slightly in Queen Charlotte Sound (5 A/B). Recommended harvest rates in other commercial areas (5 C/D/E) remained virtually the same in the 1999 and 2000 fishing seasons.

Outlook

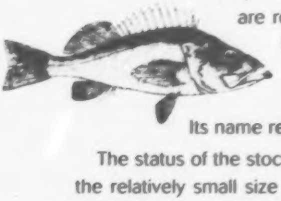
The stocks are probably close to maximum exploitation at present but actual status is poorly known. The current quota recommendations are 350–525 tonnes for the southern stock and 200–400 tonnes for the central stock. The future outlook for the canary rockfish is unknown, but harvests are expected to remain at their current level.

Silvergray Rockfish

Background

The silvergray rockfish (*Sebastes brevispinis*) is an important component of the rockfish catch in coastal B.C.'s commercial trawl fishery. It ranges from southern California to the Bering Sea. Adults tend to be captured in waters 100–375 metres deep. The principal area of commercial abundance is the coastal area of B.C., although minor fisheries exist in Washington and southeastern Alaska.

Recruiting to the fishery begins at age eight or nine and individuals can live to up to 80 years. Mating takes place in the spring and free-swimming larvae are released in mid-summer. Males and females mature between the ages of eight and 15 years. This species appears to feed on krill and small fish, including herring, and is typically found in areas of high relief near the edge of the continental shelf. Its name refers to the silver-gray colour over the length of its body.



The status of the stock is unknown. Abundance surveys are impractical because of the relatively small size of the individual stocks and their affinity for depths partially unreachable by trawlers.

Fishery Management

For stock assessment and management, silvergray rockfish in Canada's west coast waters are treated as four stocks: the west coast of Vancouver Island, Queen Charlotte Sound, Hecate Strait, and the west coast of the Queen Charlotte Islands. Stock boundaries are unknown, however, and the status of all stocks is poorly known because of the lack of a credible abundance index and limited numbers of samples.

The fishery by Canadian vessels began in the 1960s, with the first recorded landings for this species made in 1967. The Hecate Strait and Queen Charlotte Islands fisheries did not start until the late 1970s. Bottom trawling is the principal fishing mode, but there is also a growing hook-and-line fishery. In addition, the Pacific ocean perch fishery has recorded some incidental catches of silvergray rockfish. Total annual Canadian landings have averaged about 2,000 tonnes since the start of the fishery. Landings are approximately evenly distributed among the four stocks. Individual vessel quotas have been in place since 1997.

The stock dynamics of the species are poorly understood. Current assessment work is limited to the collection of basic landings, size and age composition data. Recent recorded landings of all four stocks (1,148 tonnes) were lower than their historical averages and below the combined total allowable catch of 1,510 tonnes. It is not known whether the failure to reach each total allowable catch is the result of the recent introduction of individual vessel quotas or reduced availability. The limited age composition data do not indicate a significant reduction in frequency of older fish and, therefore, do not imply a high exploitation rate. However, this could also be the result of poor recruitment in the 1990s.

Outlook

Future outlook for the silvergray rockfish is unknown, although harvests are expected to remain at their current level as the stocks are probably close to maximum exploitation at present.

Widow Rockfish

Background

The widow rockfish (*Sebastes entomelas*) is an important component of the rockfish catch in the commercial trawl fishery off Canada's west coast. It ranges from southern California to the Gulf of Alaska and is found over bottom depths of 50–375 metres, although schools are occasionally observed over deep ocean waters off the continental shelf. The principal area of commercial abundance is the coastal area of northern California to central B.C.

Widow rockfish begin recruiting to the fishery at age five and can live up to 58 years.

Mating takes place in late fall and free-swimming larvae are released in late winter or early spring. Males and females mature between the ages of five and 14. The species appears to feed on euphausiids, shrimp and small fish, including herring.

Fishery Management

The commercial widow rockfish fishery began in 1986. Landings peaked at approximately 4,500 tonnes in 1990, with an average annual coastwide landing since 1987 of 2,250 tonnes. Most commercial landings come from mid-water trawl fishing. A significant "nuisance" bycatch is reported in the salmon troll fishery as well.

For stock assessment and management purposes, widow rockfish are separated into one coastal stock in B.C. and another in the California-Washington region. Commercial catches are made in depths of 100-200 metres with mid-water trawls in Canada. Most widow rockfish landings come from the northwest coast of Vancouver Island and the Queen Charlotte Sound region of the central B.C. coast. Major fishing grounds include the area west of Triangle Island off the northwest coast of Vancouver Island in the winter and the Goose Island bank in central Queen Charlotte Sound in the summer. Widow rockfish are often caught with yellowtail rockfish (S. *flavidus*), as both species appear to favour bottoms of high relief near the edge of the continental shelf.

Since 1993, managers have used a combination of a coastwide quotas and trip limits. Annual quotas are not always achieved. Individual vessel quotas have been in place since 1997.

While the widow rockfish is a valuable food fish, it does not keep as long as other rockfish, a characteristic that tends to reduce demand. Fishers also report that its distribution is difficult to predict and thus landings are highly variable.

Stock dynamics for the species are poorly understood. The stock is probably close to maximum exploitation at present, but its actual status remains unknown. Landings of widow rockfish were 1,137 tonnes in 1997, lower than the historical average of 2,462 tonnes and lower than the 1997 total allowable catch of 2,358 tonnes. It is not known whether the failure to reach the total allowable catch is the result of the introduction of individual vessel quotas or reduced availability.

Current assessment work includes experimental acoustic biomass estimation in addition to routine collection of landings data and biological data. The studies have focused on acoustic estimates of a large mid-winter aggregation near Triangle Island off the northwest coast of Vancouver Island. In 1998, this aggregation was estimated to be approximately 2,200 tonnes. This was not sufficient to raise coastwide yield recommendations from the current precautionary levels.

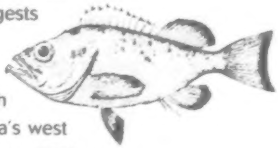
Outlook

No significant change in the level of the harvest is expected. The current quota recommendation of 1,100–3,000 tonnes is intended as an interim yield until a time-series of age composition data is available. It also reflects the lessons learned from the "boom-and bust" fishery in the U.S., where an unrestricted fishery led to landings of 28,000 tonnes in the early 1980s, only to be followed by a rapid decline. Quotas were implemented in 1983 and have been lowered steadily to the point where current recommendations are for less than 6,000 tonnes. The U.S. stock appears to be suffering from a sustained period of poor recruitment.

Redstripe Rockfish

Background

Redstripe rockfish (*Sebastes proriger*) range from southern California to the Bering Sea between depths of 12 and 425 metres. They are generally found over high-relief, rocky bottoms and can often be found at mid-water depths. They can occur singly but most often form dense aggregations. Evidence suggests that redstripe rockfish schools remain near the bottom during the day but rise up and disperse at night.



Redstripe rockfish may live to about 50 years of age, although data from 1990–92 indicate that the mean age along Canada's west coast is 20 years, with a maximum of 48 years. Redstripes reach a maximum size of about 60 cm, but are generally smaller than other slope rockfish species. In B.C., the mean length is 33 cm with a maximum length of 49 cm. Males and females reach 50 per cent maturity at a length of about 28 cm. Spawning occurs from May to July. Fertilized eggs remain within the ovary until larval extrusion and may obtain at least some of their nutrition from the female parent during development.

A biomass survey of the southwest coast of Vancouver Island in 1996 indicated a redstripe rockfish biomass of just under 1,000 tonnes, or slightly less than half of the biomass estimate for Pacific ocean perch. Goose Island Gully surveys conducted in 1994 and 1995 provided estimates of redstripe rockfish relative biomass at 2–3 per cent and 6 per cent, respectively, of the corresponding Pacific ocean perch biomass. However, on all of these surveys data were collected using bottom trawls alone and Pacific ocean perch were the target species. A comparison of 1995 commercial mid-water and bottom trawl catches suggests that approximately half of the redstripe rockfish catch was harvested by mid-water trawl. Thus, the actual biomass of redstripe rockfish might be considerably greater than has been estimated in recent surveys.

Fishery Management

A trawl fishery for redstripe rockfish and other slope rockfish has existed on Canada's west coast since the 1940s. A foreign fishery was active coastwide between 1956 and 1982, with the largest catches landed by Soviet and Japanese fleets between 1965 and 1970. In the early years of the Canadian trawl fishery, statistics were confounded by the practice of reporting the catch of several similar species under one category such as "ocean perch" or "red rockfish". However, reporting has improved since the late 1970s.

Redstripe rockfish are predominately taken by trawl gear near the bottom and at mid-water depths. Hook-and-line catches are minimal. The largest catches occur in Goose Island and Mitchell's gullies of Queen Charlotte Sound with smaller catches taken off the west coast of Vancouver Island and in Moresby Gully. Catches from the west coast of Queen Charlotte Island are minor. Prior to the 1994 introduction of port monitoring, redstripe rockfish catch figures may have been inflated by landings of misidentified Pacific ocean perch. For example, the 1992 reported redstripe rockfish catch from Goose Island Gully is double the reported Pacific ocean perch catch, while the 1996 reported redstripe rockfish catch is roughly one-quarter of the Pacific ocean perch catch. The discard rate for redstripe rockfish is considerably higher than for other slope rockfish because of their smaller size.

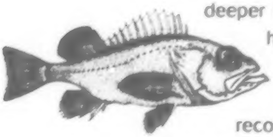
Outlook

Limited data gathered between 1990 and 1992 suggest that 1982 was the last year that a significant recruitment event occurred in the redstripe rockfish stocks in coastal B.C. waters. Therefore, abundance is expected to decline until the next major recruitment takes place. Such an event would likely not become evident in age data from the fishery until fish reach the age of seven.

Rougheye Rockfish

Background

Rougheye rockfish (*Sebastes aleutianus*) are an important component of B.C.'s trawl and hook-and-line fisheries. The species ranges from Japan and the Kamchatka Peninsula to the Bering Sea and Aleutian Islands, and down to southern California. They occur along the continental shelf slope at depths as shallow as 25 metres and as deep as 2,830 metres. Larger fish tend to lead solitary lives and live deeper than smaller fish, which form small schools. The preferred habitat consists primarily of boulder fields.



Very little is known of rougheye biology. They appear to be the longest lived of any of the B.C. rockfish, with one recorded case of a 147-year-old. Adults reach a maximum length of approximately 90 cm. Approximately half of all males are mature at 40–45 cm, and females at close to 47 cm. Both males and females are approximately 20 years old at 50 per cent maturity. April is the principle spawning period off Canada's west coast for rougheye rockfish. Fertilized eggs remain within the ovary until larval extrusion and may obtain at least some of their nutrition from the female parent during development.

A biomass survey of the southwest coast of Vancouver Island in 1996 estimated rougheye rockfish biomass at 64 tonnes. However, the survey targeted Pacific ocean perch and may have underestimated rougheye abundance. The status of rougheye rockfish in Queen Charlotte Sound is uncertain. A survey off the west coast of the Queen Charlotte Islands, including the Langara Spit region north of 54° latitude, was conducted in 1997 to estimate both Pacific ocean perch and rougheye abundance. Rougheye biomass was estimated at 4,881 tonnes, but the actual biomass may be higher as the west coast of the Queen Charlotte Islands is marked by severe topography and much of the area is not accessible to trawl nets.

Fishery Management

A foreign fishery was active coastwide between 1956 and 1984, with the largest catches landed from 1965–70. Historic catch statistics of rougheye rockfish are confounded by frequent misidentification as shortraker rockfish and other red rockfish. While shortraker rockfish catches have probably always been minor in comparison with rougheye rockfish catches, Canadian trawl landings would have underestimated rougheye relative to Pacific ocean perch throughout the 1980s.

Rougheye rockfish are targeted by both trawl and hook-and-line fleets. In 1997, the hook-and-line catch amounted to 28 per cent of the total coastwide catch of 676 tonnes. The majority of the combined catch is harvested from the southwest coast of the Queen Charlotte Islands. Other significant catches come from the southwest coast of Vancouver Island and from Goose Island and Moresby gullies in Queen Charlotte Sound.

Outlook

Quantitative biomass forecasts are currently not conducted for this species. However, based on the longevity and assumed low productivity of rougheye rockfish, stocks should remain at low levels compared with other species, such as Pacific ocean perch.

Shortraker Rockfish

Background

Shortraker rockfish (*Sebastes borealis*) are the largest of the slope rockfish, reaching lengths close to one metre. The name "shortraker" describes the stubby gill rakers. This species is easily confused with rougheye rockfish (*S. aleutianus*).

Shortrakers occur throughout the North Pacific, from Japan, the Okhotsk Sea and southeastern Kamchatka, to the Bering Sea and Aleutian Islands and down to California. They have been collected from depths of 25–875 metres. Large individuals are probably solitary and live on silt or cobble bottoms near boulders. They have been aged as old as 120 years. Adults reach 50 per cent maturity at approximately 45 cm in length. Females spawn primarily in

April. Mating occurs in the fall, and females generally release live larvae around April of the following spring. Fertilized eggs may obtain at least some nutrition from the female while in the ovary.

Fishery Management

A foreign fishery for slope rockfish, including shortraker rockfish, was active coastwide between 1956 and 1982, with the largest catches landed from 1965–70 by Japanese and Soviet trawlers. Historic catch statistics of shortraker rockfish are confounded by misidentification as rougheye rockfish. However, shortraker rockfish catches have probably always been minor compared to catches of rougheye rockfish.

Shortraker rockfish are captured by hook-and-line and trawl gear, with the largest trawl catches taken from the west coast of Vancouver Island, and the largest hook-and-line catches taken from Goose Island and Mitchell's gullies in Queen Charlotte Sound, and the west coast of the Queen Charlotte Islands.

Shortraker rockfish occur at low abundance compared with other rockfish and have always been a minor component of the trawl fishery. Historically, the quotas for shortrakers have been established through analyses of catch history and abundance estimates (relative to rougheye rockfish) from biomass surveys.

Outlook

Shortraker abundance is not expected to increase in the near future, and total allowable catch will remain low compared with other slope rockfish species.

Inshore Rockfish

Background

"Inshore" rockfish refers to species of the genus *Sebastes* that are primarily caught by hook-and-line gear in subsistence, recreational and commercial fisheries. These species include yelloweye (*S. ruberrimus*), quillback (*S. maliger*), copper (*S. caurinus*), china (*S. nebulosus*), black (*S. melanops*) and tiger (*S. nigrocinctus*) rockfish. All are commonly found from Alaska to California on rocky reef habitat, from surface waters (black rockfish) to depths of 180 metres (yelloweye rockfish).

Yelloweye rockfish are long-lived and have been aged to 117 years in B.C. coastal waters. About half are sexually mature at 18 years of age. Copper and quillback rockfish have been aged to 45 and 76 years, respectively. Rockfish generally mate in the fall and release free-swimming larvae in the early spring. Once the pelagic juveniles settle in a reef area, most inshore rockfish are thought to become resident, rarely moving from the area.

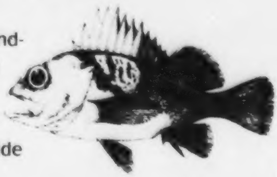
Yelloweye, quillback and copper rockfish are highly regarded food fish – yelloweyes are marketed as a fresh round and fillet product in Canada and the U.S., while quillback and copper rockfish are marketed as a premium live product in local markets.

Fishery Management

The commercial fishery is managed in each of five areas through annual total allowable catches by species aggregate. Fishing options and monthly catch limits are additional fishery management measures. Total allowable catches are monitored by dockside validation of landings. The recreational fishery is managed through daily bag limits.

Inshore rockfish are caught in a directed hook-and-line fishery and as a bycatch in all other hook-and-line fisheries, including those for halibut, salmon, dogfish and ling cod. Relatively small amounts are caught in the groundfish trawl fishery. Survey estimates suggest that the recreational catch of inshore rockfish in the Strait of Georgia may be equal to that of the commercial fishery. On a coastwide basis, recreational and First Nations harvest levels are unknown.

A category ZN licence was created for the directed hook-and-line rockfish fishery in 1986. A variety of seasonal closures and bycatch limits were applied to the ZN fishery in 1987, and total allowable catch quotas were set for the first time in 1991. Limited-entry area licensing was implemented for inside the Strait of Georgia in 1992 and for the outside in 1993.



Landings from the directed hook-and-line fishery peaked in 1995 at 2,640 tonnes, and have declined since then. A dockside monitoring program has verified landings from the directed rockfish, halibut, dogfish and ling cod fisheries since 1995. Assessment and management of the ZN fishery has focused on inshore species, although significant quantities of rougheye (*S. aleutianus*), canary (*S. pinniger*), redbanded (*S. babcocki*), silvergray (*S. brevispinus*) and shortraker (*S. borealis*) rockfish have been landed in recent years. The bycatch of rockfish in the halibut fishery is significant, reaching approximately 320 tonnes in 1998. Yelloweye rockfish, at 247 tonnes, constitute most of these landings.

Inshore rockfish grow slowly, are extremely long-lived, have low rates of natural mortality and exhibit very low stock productivity. As adults they are sedentary on rocky reef habitat and are susceptible to local depletion. Logbook data from some areas suggest progressive fleet movement to fishing grounds further from landing ports, supporting the notion of declining stocks in these areas. Logbook data also indicate a decline in catch per unit effort for quillback and copper rockfish in the Strait of Georgia over the last decade. Inshore species are thought to be fully utilized coastwide, and are likely over-utilized in the Strait of Georgia.

In each of five management regions on the coast, annual total allowable catch limits are managed for yelloweye rockfish, and for species aggregates for quillback and copper rockfish, and for china and tiger rockfish. The inside ZN fishery targets live fish, primarily quillbacks and coppers. There are three fishing options for the outside fishery: a live option that targets quillback and copper rockfish; a yelloweye rockfish option; and a deep water option that targets redbanded, rougheye and shortraker rockfish. Each option has a different catch and bycatch limit. The directed halibut fishery is permitted to retain a portion of rockfish with the halibut catch. The recreational fishery is constrained by a daily bag limit, with specific restrictions on the retention of yelloweye rockfish.

Alternatives to traditional management methods, which involve long-term area closures, are being considered for all parts of the coast.

Outlook

Traditional assessment and management methods have not been successful for inshore rockfish because of their longevity and sedentary habits, and the lack of an abundance-based population index. It is unclear whether catch per unit effort indices derived from logbook records are proportional to stock abundance. Because of the sedentary nature of the species, catch and effort indices summarized over large areas may remain high as successive reefs within the area are depleted. Thus, population depletion may be masked by the resolution of available data. Catch rates for the Strait of Georgia have declined over the last decade, in part due to increasingly stringent management measures. The lack of a reliable estimate of abundance and a time series of catch-at-age information hampers traditional fisheries assessment methods.

Biologists are currently evaluating underwater video technology in association with remote habitat classification systems to directly estimate inshore rockfish abundance. Characteristics of yelloweye and redbanded rockfish in heavily and lightly exploited areas are being studied to determine harvesting impacts on population biology.

Recent research shows that inshore rockfish populations are at low levels of abundance. Fisheries and Oceans has made a commitment to consult with all fishing sectors to develop suitable measures for species conservation. This means improving recreational fishing surveys for the collection of rockfish catch data, encouraging species reporting in the aboriginal fishery, and placing observers on commercial fishing boats.

In 1999, a strategic planning process was initiated into the assessment and management of inshore rockfish. Fisheries and Oceans Canada, along with commercial, recreational and First Nations stakeholders, developed a shared vision of inshore rockfish fisheries and a rockfish management plan to resolve problems identified in assessments. The committee addressed: increased gear selectivity, expanding area closures, evaluating alternative options to reduce catch and release in the recreational fishery (lower bag limits), and reviewing management options for addressing the localized nature of many depletions (area licensing).

To that end, Fisheries and Oceans Canada implemented rockfish protected areas (RPAs) with the intent to: protect and maintain spawning biomass, provide harvest limitation independent of a biomass estimate and target exploitation rate, select for larval dispersal over adult dispersal, establish and maintain natural size and age structure of a population, preserve essential fish habitat, and provide control communities as bench marks for comparison with open areas to estimate harvest effects.

Area closures for both recreational and commercial fisheries have been announced. Preliminary closures for rockfish identified for the commercial fishery. Catch reductions are another part of the conservation strategy announced in the management plan. The total allowable catch (TAC) in 1999-2000 for quillback, copper, china and tiger rockfish was reduced by 25 per cent coastwide from 1998-1999 levels. Also, the TAC for Yelloweye has been reduced by 10 per cent, which, combined with restriction measures in the halibut fishery, will reduce Yelloweye removals by approximately 25 per cent overall.

Other changes in the hook and line fishery include the placement of observers on selected vessels to estimate total rockfish catches. They will monitor fishing activity, examine fishing gear, record scientific data, take samples, estimate the weight and identify the species of fish caught, and inspect fishing records. Dockside monitoring is also an integral part of the management plan.

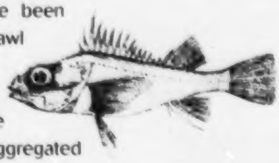
The Groundfish Hook and Line Advisory Committee and Fisheries and Oceans are also concerned about the highgrading of rockfish. Highgrading is the culling of legal-sized, lower quality rockfish from the catch, to keep only the better quality higher value fish. These concerns stem from the almost total mortality associated with discarded rockfish and its impact on stocks. Discarding of legally caught rockfish is prohibited.

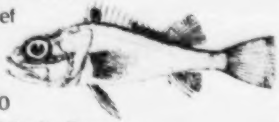
Rockfish are often a bycatch in the halibut fishery and, as a precautionary management strategy to protect inshore rockfish stocks, RPAs were introduced into the 2000 halibut management plan to address rockfish conservation and bycatch strategies. Similar measures to expand rockfish protection into lingcod and dogfish management plans are also proposed.

Thornyhead Rockfish

Background

Since the early 1980s, longspine thornyheads (*Sebastolobus altivelis*) and shortspine thornyheads (*Sebastolobus alascanus*) have been increasingly important commercial species in the B.C. trawl fishery. The largest catches are taken in deep waters off the southwest coast of Vancouver Island. The two species overlap in distribution and have similar appearances. Unlike many other rockfish species, thornyheads are not found in aggregated schools but instead exhibit a more uniform distribution over soft sediments. They are often found near rocks or other high-relief structures.





Longspine thornyheads occur from the southern tip of Baja California to the Aleutian Islands at depths of 370 to 1,600 metres. Shortspine thornyheads are found from northern Baja to the Bering Sea, and as far as the Commander Islands north of Japan, at depths between

90 and 1,460 metres. Shortspine thornyheads migrate into deeper water as they increase in size, but this behaviour has not been observed for longspines.

Adult longspine thornyheads can reach lengths of approximately 35 cm while shortspines can reach lengths of 70 cm or more. Shortspines are difficult to age but are thought to live at least 62 years and possibly more than 100 years. Longspines, which are not as difficult to age, have been estimated to reach ages of approximately 50 years.

The length at which 50 per cent of the fish are sexually mature is about 23 cm for shortspines and 16 cm for longspines. Both species reach 50 per cent maturity at approximately 12 years. Both species spawn in the spring and produce a jellied egg mass consisting of between 20,000 and 450,000 eggs. The egg mass floats to the surface where final development and hatching occurs. The larval and pelagic juvenile phases last 18–20 months for longspine thornyheads and 14–15 months for shortspines. Juvenile longspines settle on the continental shelf slope at depths of 600–1,200 metres, while juvenile shortspines settle at depths of approximately 100 metres, migrating into deeper water as they grow.

Fishery Management

Longspine and shortspine thornyheads are taken almost exclusively by trawl gear. Longspines, considered tolerant of low oxygen levels, are found in deeper water than shortspines and are fished primarily off the west coast of Vancouver Island at depths of between 700 and 1,000 metres. Shortspine thornyheads are fished along the entire coast in waters between 150 and 550 metres deep. The coastwide trawl catch of thornyheads has increased more than 10-fold since the mid-1980s, spurred by foreign market demand.

Thornyheads are considered a specialty fish, used whole for ceremonies and frozen for high-end users in Japan. Fish quality is essential and the short (three-day) holding time, combined with limited port access, previously made fishing for thornyheads uneconomical and impracticable. With the increase in frozen at sea (FAS) technology within the trawl fleet and the implementation of individual vessel quotas, fishers can now specialize in these species without forgoing other fishing opportunities. The price for fresh thornyheads in 1999 was approximately $0.80–$1.30/lb and up to $4.00/lb for FAS fish, intensifying directed fishing effort.

On the west coast of Vancouver Island, longspine thornyheads account for more than 70 per cent of the total thornyhead catch, mainly due to the availability of deepwater trawl locations. Catches have been steadily increasing in recent years, however, the latest analyses indicate a possible decline in catch per unit effort in this area. Biomass indices in neighbouring U.S. regions to the south have been declining. Throughout the rest of the coast, longspine thornyhead catches are relatively minor.

Catches in Goose Island, Mitchell's, and Moresby gullies of Queen Charlotte Sound and Hecate Strait consist almost entirely of shortspine thornyheads (about 90 per cent). Catches declined between 1996 and 1997, but these declines may reflect the change in management that coincided with the introduction of individual vessel quotas in 1997. Trawlable grounds off the west coast of the Queen Charlotte Islands are limited by severe topography and catches are relatively low. Shortspine thornyheads make up almost all of the thornyhead catch possibly due to the lack of deepwater trawl sites. However, it is also possible that deepwater trawling for longspines may increase in this area if it becomes economically feasible. Declines in catches between 1996 and 1997 are likely due to changes in management brought about by the individual vessel quota system.

Recent downward trends in catch per unit effort have highlighted the need for a more comprehensive assessment of these species. However, accurate catch-at-age data have been unavailable due to the difficulty in obtaining reliable age data by methods now in use. In addition, research surveys have never focused on thornyhead stocks but have peripherally assessed these species while targeting more traditional commercial stocks, such as Pacific ocean perch.

Outlook

Quantitative biomass surveys have not been conducted for thornyheads and there is much uncertainty regarding stock status. Downward trends in catch per unit effort suggest that current levels of harvest may be too high in some areas of the coast.

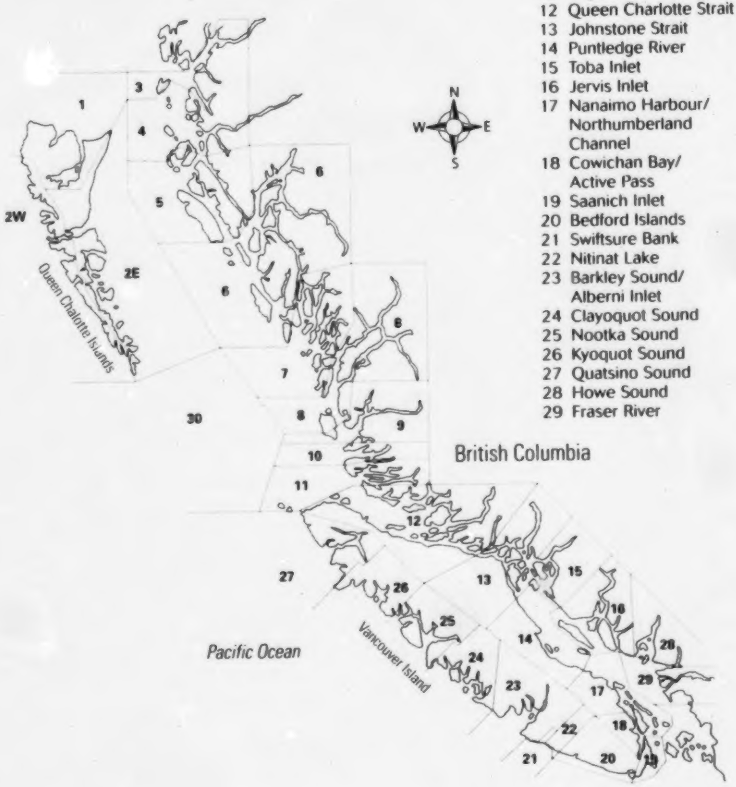
Pelagics

Management Areas

Northeastern Pacific Ocean

"Pelagics inhabit the open, upper waters of the ocean rather than waters adjacent to land."

1 Masset Inlet
2 Queen Charlotte Island
3 Nass River
4 Skeena River
5 Hecate Strait
6 Kitimat River
7 Milbank & Mathieson Sounds
8 Burke Channel
9 Rivers Inlet
10 Cape Caution
11 Cape Scott
12 Queen Charlotte Strait
13 Johnstone Strait
14 Puntledge River
15 Toba Inlet
16 Jervis Inlet
17 Nanaimo Harbour/ Northumberland Channel
18 Cowichan Bay/ Active Pass
19 Saanich Inlet
20 Bedford Islands
21 Swiftsure Bank
22 Nitinat Lake
23 Barkley Sound/ Alberni Inlet
24 Clayoquot Sound
25 Nootka Sound
26 Kyoquot Sound
27 Quatsino Sound
28 Howe Sound
29 Fraser River



Pelagics

Pelagic is a broad term applied to fish that inhabit the open, upper waters of the ocean rather than waters adjacent to land. Pelagic fish, such as herring and eulachon, swim in large schools, which provide effective protection from predators. However, it also makes them susceptible to large fluctuations in biomass and prone to stock collapses. Successful management of this resource is critical as natural population fluctuations precipitate over-harvesting, and oceanic conditions and environmental degradation can quickly harm the abundance of these species.

Pelagic fish rear in intertidal or freshwater environments, but quickly move out to the ocean where they live for two to five years until they sexually mature. They migrate closer to shore to spawn, usually between the months of February to May. Herring sexually mature at three years of age. They migrate closer to shore to spawn in subtidal areas, and return to open ocean feeding areas. Herring can live up to 15 years, successfully spawning numerous times. In contrast, eulachon sexually mature between the ages of two and five and return to freshwater rivers to spawn. Many adult eulachon die after spawning, making it improbable that eulachon spawn more than once.

Eulachon

Background

Eulachon *(Thaleichthys pacificus)* are small anadromous fish that occur from the southern Bering Sea to northern California. Within their range, eulachon spawn only in 30–40 rivers, about 15 of them in B.C. All known eulachon spawning rivers experience increased spring runoffs, known as freshets, and most drain snowpacks or glaciers. On rare occasions, eulachon spawn in other rivers, such as the Somass on Vancouver Island.

Eulachon spawning is limited to the lower reaches of rivers and often is accompanied by spectacular throngs of predatory sea lions and birds. Their small adhesive eggs, about 30,000 per female, attach themselves to sand or pebbles and hatch in three to five weeks at ambient temperatures, usually from 3–10 C. Spawning begins in early March in most B.C. rivers, such as the Skeena and Nass, but occurs as late as April and May in the Fraser.

Once hatched, larvae are rapidly flushed to marine waters, where they begin a two- to five-year period at sea to reach maturity. Large post-spawning mortalities occur, with most eulachon probably dying after spawning. Adults reach a length of between 15 and 20 cm and weigh between 40 and 60 g.

Eulachon are an extremely important food source to many First Nations on the Pacific coast and play a significant role in the cultural heritage of some communities. They also support small commercial fisheries on the Fraser River. Although eulachon were once plentiful in most spawning rivers, their runs appear to have declined in a number of rivers, particularly in southern areas. The year 1994 was marked by sharp, simultaneous declines in spawning runs in the Columbia, Fraser and Klinaklini rivers (even though spawning times differ by four months), as well as low spawning runs in other B.C. rivers. It is not clear if Alaskan populations have suffered any declines.

There may be as few as 30 eulachon runs in the world. Based on preliminary genetic analyses, however, the different runs do not appear to be unique. If so, extensive straying and mixing among different rivers must occur. Further analyses are required to confirm the apparent genetic non-differentiation among rivers. However, until this is done, management should be based on the precautionary assumption that each eulachon-spawning river represents a separate biological stock. Analyses of population differences based on microchemical analyses of inner-ear structures known as otoliths were non-conclusive. Small differences occur among populations, but evidence indicates that some individuals moved among rivers. These tentative genetic and microchemistry results are consistent with the observation that eulachon runs in some rivers change with time.

Spawning sites change within the Columbia River, and occasionally eulachon spawn in previously unused rivers. For instance, when spawning runs were reduced in other rivers in 1994, an unprecedented eulachon spawning occurred in the Chehalis River, north of the Columbia, in Washington State. In the 1950s, eulachon spawned in the Somass River on Vancouver Island, and accounts exist of other unusual spawnings that do not appear to result in established eulachon runs. On the other hand, differences in run timing (March for most rivers, February for the Columbia and April for the Fraser) indicate that different runs may represent separate populations.

The causes of recent stock declines are unknown. Also, it is uncertain whether there is a single decline in a widespread stock that readily mixes among different spawning sites, or a series of synchronous declines in a number of independent populations. Widespread changes in ocean climate could explain synchronous declines in different populations with different spawning times. Changes in spawning habitat, however, would probably result in more gradual declines and not be synchronous among different rivers. The Fraser River has seen both a slow decline in abundance over the last 30 years and a sharp decline in 1994. Therefore, in the Fraser and perhaps other rivers, eulachon may be affected by changes in both habitat and ocean climate.

Fishery Management

The eulachon, unique for its high oil content, was an integral part of First Nations society before European contact. First Nations people use eulachon oil, called "grease", as a food supplement like butter. Grease is produced and refined according to tradition and traded widely throughout the west coast. In some communities, the eulachon was known as the "salvation fish" because it was the first to arrive after winter. Early European pioneers used it as a "candle fish" because when dried and burned, the oil can sustain a slow-burning flame.

Traditional fisheries for eulachon grease continue to the present on some rivers north of the Fraser. Annual landings of several hundred tonnes in the 1950s were used for animal feed and meal. Since the 1980s, the fishery has evolved into a smaller, specialized industry to supply local markets in Vancouver with fresh fish, and small non-commercial catches for human consumption continue today. Until 1994, when catches fell sharply, the Columbia River had the world's largest run, with a sustained commercial fishery of 1,000–2,000 tonnes per year and a recreational fishery about the same size. Since the 1920s, the only commercial fishery in B.C. was on the Fraser River, where each year several hundred tonnes of eulachon were used, mainly as an inexpensive food for fur farms. The more recent commercial fishery of the 1980s and 1990s takes about 30–40 tonnes per year, most of it destined for the Vancouver market.

In most other rivers, the fishery has been conducted by First Nations people. Aside from the Fraser River, annual aboriginal catch data are not available for most rivers, except for a few during the last decade. For example, on the north coast of B.C. the Haisla usually take an estimated 50–100 tonnes from rivers in the Gardner Canal and Douglas Channel area, and the Nisga'a take a similar amount from the Nass River. In the late 1890s, the Nass landings were much larger, usually exceeding 300 tonnes per year. All fishing is done on spawning runs. At peak run times, spawning eulachon can be dipped from rivers with small nets. They also can be taken with seines and gill nets.

Catch records have been maintained on the Fraser and Columbia rivers for about 50 years, but few catch data from other rivers are available. The records on the Fraser might under-represent the actual catch from the 1960s–80s because of incomplete reporting.

With the unexpectedly low biomass of returning adults in 1994 in at least three rivers (the Columbia, Fraser and Klinaklini, at the head of Knight Inlet), catches were also sharply lower than in previous years. Spawning runs were possibly lower in some other rivers, such as the Skeena and Kemano, but the decrease was most pronounced in the southern rivers. Since 1994, spawning runs have remained low in the Columbia and Fraser. Based on egg and larval surveys, the spawning biomass in the Fraser River was estimated at less than 100 tonnes for 1995 and 1997, although 1996 may have had a substantial return greater than 1,500 tonnes. Larval densities in 1998 were low, indicating a low spawning biomass. Due to stock abundance concerns in 1998 and

1999, the fishery was not opened to any sectors.

Fishing effort varies among river systems, and by year. The effort on the Nass is low compared with 90 years ago, when the Nass eulachon run constituted the fifth-largest commercial fishery in B.C. In the Skeena, effort varies and may increase during years of large runs, signaled by intense bird and mammal activity following the returning eulachon. Effort has decreased on the Kitimat because of decreased run size and polluted spawning habitat, but increased on the Kemano, partly in response to decreased availability on the Kitimat. The effort in other central coast rivers is uncertain, but more information may become available in the future. Effort in the Johnstone Strait stocks may have declined in response to an apparent decrease in run size. Effort has fallen steadily in the Fraser, in response to limited markets and decreasing availability. In the mid-1990s about 20 commercial vessels fished the Fraser River regularly.

Active management and assessment programs were introduced in 1995 in the Fraser River. The fishery was restricted to three days per week and weekly hails were required to monitor the catch. Stock assessment programs included the requirement for detailed harvest logbooks, test fisheries, biological sampling, and egg and larval surveys to estimate spawning biomass.

In 1996, more than 60 fishers entered the fishery, most in anticipation that rumoured future licence limitations would preclude them from future fisheries. The Fraser River was closed to commercial eulachon fishing in 1998 because of low apparent availability of eulachon in 1997, an estimated spawning return of less than 50 tonnes, continued low runs in the Columbia River, and low offshore abundance indices. The closure was extended to all fisheries, including aboriginal fisheries, in 1999. Limited commercial fishing opportunities (three days a week) in subareas 7–29 to 17–29 were available in 2000. This opening was subject to necessary in-season adjustments to the fishing plan based on run strength and stock abundance tested throughout the season.

Future Fraser River management will depend on the ability to assess eulachon spawning runs and establish catch targets. In many rivers, First Nations people have maintained a degree of control over the timing and location of fishing activities. Several First Nations, in cooperation with Fisheries and Oceans Canada and other agencies, have initiated stock assessment activities.

Current management activity includes the restriction of dredging activities during the eulachon spawning season. Bycatch monitoring programs, meanwhile, will determine the impact of other fisheries that capture eulachon as a non-target species. An informal Eulachon Research Council meets annually to present the latest research and collect information from local stakeholders in First Nations and commercial fisheries. Future management will depend on the ability of eulachon populations to recover. The goal is to establish a number of small, sustainable fisheries that are assessed and managed by local communities in cooperation with the federal government.

Outlook

Based on available information, particularly events of recent years, concern exists for the long-term sustainability of eulachon runs. Many runs have declined, but the reasons remain unclear. One possible explanation is climate change, specifically a warming of coastal waters where eulachon live, but there are other explanations, including subtle changes in the hydrology of the relatively small numbers of rivers used for spawning. Industrial pollution has affected eulachon in several rivers, and increased marine mammal predation may be partly responsible as well.

If a change in ocean climate is part of the ultimate cause for the decline, and if the recent warming trend continues, the long-term outlook for eulachon may be bleak. Exacerbating the situation are habitat changes in many watersheds and eulachon bycatch from offshore trawl fisheries, although the magnitude of the bycatch is unknown at present.

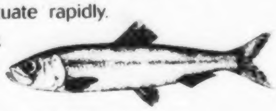
While problems are profound, the capacity for remediation is limited. Possible remedial actions include protection of spawning habitat, limiting bycatch, and regulating fisheries by conducting assessments and catch-monitoring programs. Even with concerted effort directed at these activities, eulachon runs may continue to decline because of unprecedented climate change.

The outlook could change rapidly, however, if one or two years of strong spawning runs occurred in some of the largest rivers, particularly the Fraser or Columbia. Such returns would prove that the recent decline is reversible and abundant eulachon populations can be sustained in all major spawning rivers.

Pacific Herring

Pacific herring (*Clupea pallasi*) is a pelagic species found in the inshore and offshore waters of the Northeastern Pacific from California to the Beaufort Sea. Five major herring stocks are found on Canada's west coast: Prince Rupert District, central coast, Queen Charlotte Islands, west coast of Vancouver Island and Strait of Georgia.

Herring are a small, relatively short-lived finfish, with a maximum age of 15 years. The herring population is highly dynamic, tending to fluctuate rapidly. Herring mature and recruit to the spawning stock predominantly between the ages of two and five. Within this range, age-at-recruitment tends to increase with latitude.



Stock assessments are based on biological samples of the population age composition, average weight-at-age, historical catch data, and assessments of spawn distribution and intensity throughout the coast. The fishable stock biomass is estimated by two models: an age-structured model and an escapement model. The latter relies predominantly on spawn deposition estimates. The average of the estimates for both models is used to determine the current stock level, project future run size, and recommend an allowable catch.

Since 1970, the two assessment models have displayed very different estimates of stock abundance, although the trends have remained consistent. Recent reviews of the data have improved the correspondence between the two models, but estimates of stock abundance based on the age-structured model are still unrealistically high for this stock and were not used in the assessment of stock status or forecasts of future yield. It appears that estimates of age-structure have not been collected consistently from the same locations, which may have biased estimates of abundance from the age-structured model.

In the past, herring was processed into low-value products such as fish oil or fishmeal. Currently, there are three major commercial fisheries for herring: spawn-on-kelp, roe herring, and food and bait. In the spawn-on-kelp fishery, which is conducted primarily by First Nations people, lines of kelp are suspended in open or closed ponds where herring naturally congregate to spawn. Once the spawn-covered kelp is harvested, it is trimmed, brined and shipped to Asia. Roe herring, the largest of the herring fisheries, is also destined for Asian markets. The objective of the this fishery is to obtain a low-volume, high-quality product that is both economically profitable and ecologically sustainable.

Prince Rupert District Herring

Background

The Prince Rupert District herring stock, one of the five major Pacific herring stocks found on Canada's west coast, experienced high levels of recruitment during the 1950s and early 1960s, and reduced recruitment during the late 1960s and early 1970s. The fishery was closed in this area in 1983 due to low abundance levels. The stock has subsequently rebuilt to moderate levels in the late 1980s due to strong 1981, 1984, 1988 and 1989 year-classes. Recent weaker year-classes resulted in a decline in stock size from 1992 through the present. The 1993 year-class, which recruited in 1996, appears to be above average, while the recent 1994 and 1995 year-classes are average and should result in stable stock levels in the short term.

Recent assessments indicate that the mature herring biomass remains well above the stock conservation reference point of 12,100 tonnes and should continue to sustain a modest fishery. However, there are concerns about the ability to harvest fish with gill nets given the declining size of the herring.

Fishery Management

In the Prince Rupert District, the fishery began at the turn of the century but did not become extensive until the expansion of the dry-salted fishery in the mid-1930s and a reduction fishery in the 1940s. This stock declined as part of the coastwide collapse from overfishing in the early 1960s, and the commercial reduction fishery was closed in 1967. Following a combination of favourable environmental conditions and a low harvest rate, the stock recovered by the mid-1970s.

The current roe fishery began in 1972. The target harvest rate of roe herring is fixed at 20 per cent of the forecast mature stock biomass, when the stock size is sufficiently above the threshold or minimum spawning stock biomass. The stock achieved recent high abundance levels in the late 1980s but has subsequently declined.

All herring spawning within Areas 3 to 5 are assumed to belong to the Prince Rupert stock that migrates inshore from Hecate Strait in the late fall and leaves after spawning in late March and April. From the mid-1940s until the late 1960s, these herring were harvested and processed into relatively low-value products such as fish meal and oil. The largest catch was taken in 1952, and the fishery was closed in 1953 and 1958 due to industrial disputes. Catches increased dramatically in the early 1960s but were unsustainable. By 1965, most of the older fish had been removed from the spawning population by a combination of overfishing and a sequence of weak year-classes, attributed to unfavourable environmental conditions and a low spawning biomass. As a result, the commercial fishery collapsed in 1967, and was closed by the federal government to rebuild the stock.

Following the closure, a series of above average year-classes occurred in the early 1970s, rebuilding the stock quickly and providing opportunities for a new fishery. During the closure, the small traditional fisheries continued locally for food and bait. At this time there was a growing interest in harvesting roe herring for export to Japan, where stocks had been decimated. A small experimental roe harvest began in 1971 and expanded rapidly until 1983, when fixed quotas were introduced to regulate the catch. A significant quantity of Prince Rupert District herring is also used for spawn-on-kelp and as an aboriginal food source.

The objective of the current herring fishery is to obtain a low volume, high quality product that is economically profitable and ecologically sustainable. The fishery is managed by setting a fixed quota based on a harvest rate of 20 per cent of the forecast mature stock biomass. To meet conservation objectives, the management strategy also enforces a minimum spawning stock biomass. If the forecast biomass falls below 12,100 tonnes, the commercial fishery is closed to allow for stock recovery. Since the latter conservation management measure was first implemented, there has been a substantial reduction in the amount of excessive harvesting in these fisheries. In 1998, pool fishery management was introduced to the roe herring fishery as a management tool for controlling harvest, especially in the seine fishery. In response to reduced stock levels, the Prince Rupert District fishery was closed in 1983. Subsequently, the stock has rebuilt and sustained an average catch of 4,700 tonnes over the past decade. Total herring landings in British Columbia in 1999, at 28,800 tonnes, were 12 per cent lower than in 1998. The roe herring and spawn-on-kelp total allowable catch (TAC) in the Prince Rupert District decreased to 2,540 tonnes in the 1999 and 2000 fishing seasons. A similar TAC is predicted in 2001.

Outlook

Since very little is known about the factors that affect recruitment, it is difficult to forecast future stock trends. However, the recent history of recruitment to the stock has indicated a good year-class occurring every fourth year, a pattern similar to that in southeastern Alaska. If this pattern continues, it will result in increased stock stability and resource levels that should sustain current levels of harvest.

Central Coast Herring

Background

All herring spawning within the central coast of B.C. are assumed to belong to a single stock. For stock assessment purposes, this includes fish that spawn in Kitasu Bay as well as all of Area 7, and Kwakshua Channel in Area 8.

The central coast stock reached near historic high levels of abundance in the late 1980s and early 1990s. This was due to the unusually strong 1985 and 1989 year-classes recruiting to the stock. Subsequently, the stock declined due to poorer recruitments. The recent increase in abundance is due to the strong recruitment of the 1994 and 1995 year-classes. They should maintain the stock at healthy levels for the next few years.

Between 1896 and 1936 the catch from this stock averaged 131 tonnes, most of which was used for bait. The reduction fishery expanded into the central coast in the late 1930s. Catches averaged 35,200 tonnes from 1937 until 1967, when the stock collapsed from overfishing. The commercial reduction fishery was then closed.

The combination of favourable environmental conditions and a low harvest rate allowed the stock to recover by the mid-1970s. The target harvest rate of roe herring is fixed at 20 per cent of the forecast mature biomass, when stock size is sufficiently above the threshold or minimum spawning stock biomass (cutoff). The stock achieved recent high abundance levels in the early 1990s, declined over several years, and has increased in recent years.

Fishery Management

The evolution of the commercial fishery for central coast herring has closely paralleled that of the Prince Rupert District, including the 1967 collapse of the fishery and subsequent four-year closure. The stock rebounded enough so that by 1972, the growing interest in harvesting roe herring for export to Japan led to a small experimental harvest of central coast stocks. The fishery expanded until 1983, when fixed quotas were introduced to regulate the catch. Small quantities of central coast herring are also used for spawn-on-kelp and as a food source by First Nations people.

The fishery is currently managed by setting a fixed target harvest rate of 20 per cent of the forecast mature stock biomass. To meet conservation objectives, the management strategy also enforces a minimum spawning stock biomass. If the forecast biomass falls below the cutoff threshold of 17,600 tonnes, the commercial fishery will be closed until the stock rebuilds. In response to reduced stock levels, the central coast fishery was closed in 1979 and 1980. Since then the stock has rebuilt to a peak abundance in 1992 and has sustained an average catch of 9,000 tonnes over the past decade.

Outlook

The recent increase in abundance of central coast herring is due to the strong recruitment of the 1994 and 1995 year-classes. It is expected the stock will remain at healthy levels for the foreseeable future.

Queen Charlotte Islands Herring

Background

Various studies have suggested that herring recruitment is determined by variations in the size of the parent stock, and environmental conditions during the first year of life. Recruitment variability in the Queen Charlotte Islands (QCI) herring stock has been correlated with March sea surface salinities and sea levels in the stock area during the year of birth. Although there is a risk that these correlations might not be meaningful, they could have a biological basis. For example, variations in surface salinity and sea level reflect differences in wind-induced upwelling and mixing, freshwater runoff and nutrient supply. These factors could affect the supply of the plankton on which young herring feed, and indirectly alter juvenile herring losses to predators. Research on these factors is being pursued.

Historically, the 1977 year-class was exceptional. It produced the largest recruitment to the Queen Charlotte Islands stock in the last 40 years. The 1951 year-class was also very strong. Since 1980, however, nine of the last 18 year-classes have been of below average strength. The three year-classes between 1993 and 1995 have been above average, resulting in the rapid recovery of stock abundance following the fishery closure from 1994–96.

Fishery Management

The Queen Charlotte Islands assessment region extends from Cumshewa Inlet in the north to Louscoone Inlet in the south. All herring spawning within this area are treated as a single stock that migrates inshore in the late fall and leaves after spawning in late April.

Catches were first reported from this area in 1937. From the mid-1940s until the late-1960s, this stock, like all B.C. herring was harvested primarily for fish meal and oil. As the fishery expanded, commercial harvest rates increased sharply and were unsustainable by the late 1950s. A record high catch of 77,500 tonnes was removed from the Queen Charlotte Islands assessment region in 1956. This fishery was closed in 1953, and was disrupted by labour disputes in 1958.

Although the stock was not fished commercially in 1960, when it was fished it was harvested as heavily as the other major stocks. By 1965, most of the older fish had been removed from the spawning population by a combination of overfishing and a run of poor year-classes (born between 1954 to 1957). Consequently, the commercial fishery collapsed in 1967, and the fishery was closed by the federal government to allow the stock to rebuild.

The commercial fishery remained closed for four years. During this period, only small, traditional harvests for local food and bait were permitted. Fortunately, while the fishery was closed, there was a run of five above-average strength recruitments, which enabled the stock to recover, and the fishery to reopen in 1972. At that time, there was a growing interest in harvesting B.C. roe herring for export to Japan. Small quantities of herring were also utilized for spawn-on-kelp, and for aboriginal food, social and ceremonial purposes.

The fishery is currently managed by setting a fixed target harvest rate of 20 per cent of the forecast mature stock biomass. To meet conservation objectives, the management strategy also enforces a minimum spawning stock biomass. If the forecast biomass falls below the cutoff threshold of 10,700 tonnes, the commercial fishery is closed until the stock rebuilds.

Low stock levels caused the Queen Charlotte Islands roe fishery to be closed in 1988. In 1994, the forecast run was close to the cutoff, so fishing was restricted to aboriginal food fish and commercial spawn-on-kelp. In 1995 and 1996, only food fishing was permitted. Abundance rebounded in 1997, but a cautious approach was taken to resuming harvest of the stock and only limited spawn-on-kelp activity was permitted. A small roe fishery took place in 1998 while the stock continued to rapidly rebuild.

The estimated spawning biomass in 1998 was 21,000 tonnes, based solely on the escapement model, placing the stock well above the harvesting threshold and supporting the decision to resume the roe fishery. Herring stocks in 1999 are at a healthy abundance level and conservation measures first implemented in 1998 will continue in the coming season. These conservation measures include the application of a fixed harvest rate of 20 per cent in all major stock areas and pool fishery management. Since the latter conservation management measure was first implemented, there has been a substantial reduction in the amount of excessive harvesting in these fisheries.

Although the Queen Charlotte Islands stock declined slightly in 2000, it remained strong enough to allow a roe herring fishery. However, stock abundance dipped below the fixed harvest rate in 2001 and the roe herring fishery would not open. A limited spawn-on-kelp fishery is available in 2001 with at TAC of 450 tonnes.

Outlook

Due to some uncertainty in the age-structured model performance, forecasts are based solely on the escapement model. However, as very little is known about the factors that affect recruitment to the Queen Charlotte Islands stock, it is not possible to forecast the stock biomass trend more than one year in advance.

Strait of Georgia Herring

Background

All herring spawning within the Strait of Georgia are assumed to belong to a single stock that migrate into the strait in the late fall and leave after spawning, in March and April. Many areas in the Strait of Georgia retain some resident or non-migratory herring throughout the summer, but the distribution and abundance of non-migratory fish changes among years. For stock assessment purposes, these fish are considered as part of the Strait herring stock

The Strait of Georgia stock has enjoyed a series of strong recruitments throughout the 1980s and early 1990s, which have increased the abundance to near high levels historically.

Fishery Management

The Strait of Georgia herring stock has been fished since 1887. Catches increased from 500 tonnes in 1900 to about 35,000 tonnes in 1927 due to the expansion of the Asian market for dry-salted herring. The annual catch dropped between 1927 and 1935 due to market loss.

From the late-1930s until the late-1960s, herring were harvested widely within the strait and processed into relatively low-value products such as fish meal and oil. Commercial harvest rates increased progressively and were unsustainable by the early 1960s. The commercial fishery collapsed in 1967, and was closed by the federal government for four years to allow the stock to recover.

The stock rebuilt enough to sustain a new fishery beginning in 1972 – roe herring for export to Japan. The fishery expanded until 1983, when fixed quotas were introduced to regulate the catch. The roe fishery is localized within the strait and concentrates on the large bodies of fish in the major spawning locations. The Strait of Georgia stock also supports small food, bait and charity fisheries, as well as fisheries for zoo and aquarium food.

The target harvest rate for the herring resource is fixed at 20 per cent of the forecast mature stock biomass, when stock size is above the threshold or minimum spawning stock biomass. If the forecast biomass falls below the cutoff threshold of 21,200 tonnes, the commercial fishery is closed until the stock rebuilds.

The stock achieved recent high abundance levels in the late 1970s, declined until the mid-1980s and was closed in 1986. Since then the stock rebuilt to a recent high abundance in 1992–93 and has sustained an average catch of 12,900 tonnes over the past decade. It is now near peak levels.

Outlook

Given the current large biomass, the stock is expected to continue to support moderate fisheries over the next several years. Management measures were implemented in 1998 to control excessive fishing effort and ensure conservation. These measures include coast-wide pool fisheries for both seine and gillnets, a limit of two licences per vessel for seines and double licensing for gillnets participating in the large gillnet pool fishery in the Strait of Georgia. Both seine and gillnet pools will be allowed to fish independently to attain their catch targets.

Stock abundance in the Strait of Georgia has remained strong since 1999. The TAC for the roe herring fishery is set for 15,330 tonnes. The spawn-on-kelp fishery in this run has been closed since 2000.

West Coast Vancouver Island Herring

Background

All herring spawning within Areas 23–25 are assumed to belong to a single stock that migrates inshore in the late fall and leaves, after spawning, in late February and March. Research has shown that the growth and survival of the west coast of Vancouver Island (WCVI) herring are sensitive to natural variations in ocean climate. These recurring climatic changes, which last for a decade or two, cause significant shifts in the structure and productivity of the coastal ecosystem where the herring live. Specifically, the productivity of the WCVI herring stock is vulnerable to interannual and decadal time scale variations in the climate of the coastal ocean (indexed by water and air temperatures, which are highly correlated), and spawning biomass.

Recruitment is the most important process determining the productivity of the herring populations on Canada's west coast. Long-term research has shown that both recruitment and adult survival tend to be below average in warm years, particularly when migratory herring predators (such as Pacific hake and mackerel) are abundant off the west coast of Vancouver Island. The coastal ocean has been in a protracted warm state since 1978. When this occurs, the productivity of the copepod and krill population appears to decline. Also, more Pacific hake migrate for the summer to the WCVI stock assessment area, where they eat significant quantities of herring. Pacific mackerel and hake are particularly abundant during warm El Niño summers.

Retrospective estimates of the mature stock (age two and older) biomass just prior to the fishery, indicate a peak in the mid-1970s in response to favourable environmental conditions and low harvest rates. As the stock approached its carrying capacity, the net production rate fell, causing a decline in the late 1970s. The ocean climate shifted to a warm state in 1978 and has remained anomalously warm since then (with the exception of 1985, which was a cool year).

The recent period of low stock biomass and productivity has been associated with a series of warm years. There was a minor increase in the biomass in 1988, when the above-average 1985 year-class recruited. However, as this year-class aged and declined in abundance, so has the stock biomass. The stock biomass increased in 1997 with the recruitment of the above average 1994 year-class, which was born in a year of average temperatures. The 1995 year-class, which recruited in 1998, is poor.

Stock reconstructions indicate that herring born in cool years are twice as large on average as those born in warm years. Surplus production calculations indicate that the unfished carrying capacity of the WCVI population is about 111,000 tonnes when the environment and ecosystem are in a cool climate state, but is less than half as large (about 49,000 tonnes) during warmer conditions. Retrospective stock production analyses indicate that the WCVI stock can sustain catches exceeding 20,000 tonnes during cool climate states. However, the sustainable catch is less than 8,000 tonnes during warm climate states.

The stock biomass in 1998 just prior to the fishery was estimated to be about 44,000 tonnes. Based on surveys of the offshore stock in August 1998, recruitment of the 1996 year-class is expected to be poor. The recent pattern of a generally below-average recruitment to the stock is not expected to improve until the current warm climate moderates and returns to an average or cool state.

Fishery Management

Between 1918 and 1966, the catch from the WCVI stock averaged 18,000 tonnes. From the mid-1940s until the late 1960s, herring from this stock were harvested and processed (reduced) into relatively low value products such as fish meal and oil. Like other herring stocks on Canada's west coast, the commercial harvest rates increased during this period and were unsustainable by the early 1960s. By 1967, the commercial fishery collapsed and was closed for four years by the federal government to allow the stock to recover.

In 1972, the WCVI stock also supported a new experimental fishery for roe herring exported to Japan. The fishery expanded until 1983, when fixed quotas were introduced to regulate the catch. Small quantities of WCVI herring are used for spawn-on-kelp and aboriginal food fisheries.

The target harvest rate of roe herring is fixed at 20 per cent of the forecast mature stock biomass, when the stock size is sufficiently above the threshold or minimum spawning stock biomass of 18,800 tonnes. Unfavourable oceanic conditions returned in 1978, and the stock has been in a low productivity state since that year.

Outlook

Recent assessments indicate that the mature herring biomass is rebuilding and is moderately above the stock conservation threshold. In response to several years of poor recruitment, the WCVI fishery was closed in 1985 and 1986. Since then, the stock has been in a low productivity state and has only been able to sustain an average catch of about 7,500 tonnes. Under current environmental conditions, the stock sustained a small catch of less than 8,000 tonnes in 1998. Herring abundance remained stable on the west coast of Vancouver Island (WCVI) in 1998 and 1999 allowing for moderate fishing opportunities. However, stock abundance indicated levels below the commercial fishery cut-off level in 2000 and 2001and the WCVI roe herring fishery was closed due to conservation measures. A limited spawn-on-kelp fishery is available in 2001.

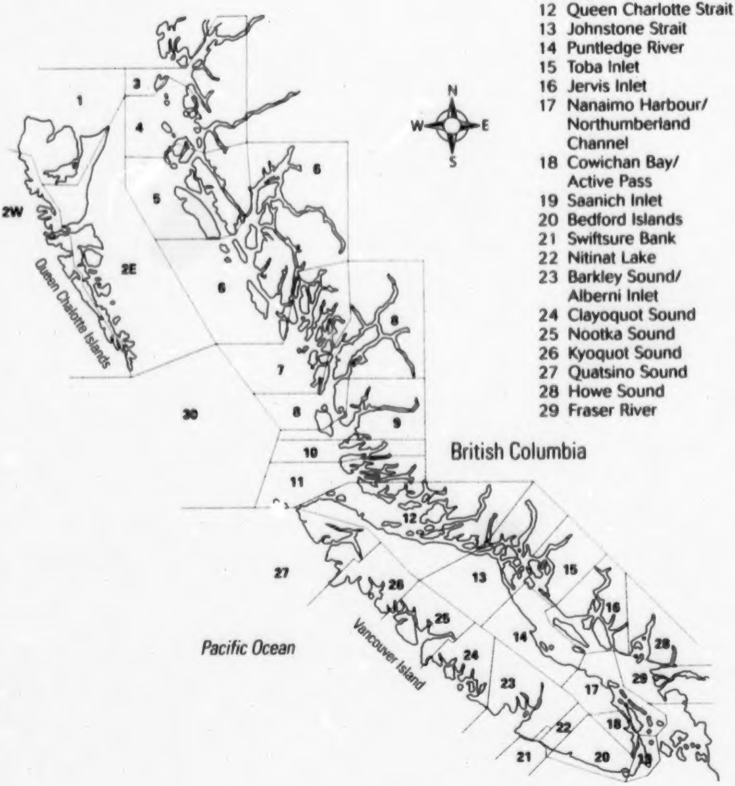
Invertebrates

Management Areas

Northeastern Pacific Ocean

"More than forty invertebrate species are managed on the Pacific coast."

1 Masset Inlet
2 Queen Charlotte Island
3 Nass River
4 Skeena River
5 Hecate Strait
6 Kitimat River
7 Milbank & Mathieson Sounds
8 Burke Channel
9 Rivers Inlet
10 Cape Caution
11 Cape Scott
12 Queen Charlotte Strait
13 Johnstone Strait
14 Puntledge River
15 Toba Inlet
16 Jervis Inlet
17 Nanaimo Harbour/ Northumberland Channel
18 Cowichan Bay/ Active Pass
19 Saanich Inlet
20 Bedford Islands
21 Swiftsure Bank
22 Nitinat Lake
23 Barkley Sound/ Alberni Inlet
24 Clayoquot Sound
25 Nootka Sound
26 Kyoquot Sound
27 Quatsino Sound
28 Howe Sound
29 Fraser River



Invertebrates

Invertebrate is a broad term applied to any animal lacking a backbone or spinal column. Scientists have identified approximately 8,000 different invertebrate species in B.C.. Physical characteristics, life histories and spawning habits vary greatly from species to species. They are classified into broadly related groups, including sponges (phylum *Porifera*); hydroids, corals and anemones (*Cnidaria*); comb jellies (*Ctenophora*); a variety of worms (*Annelida, Nemertea, Platyhelminthes*); "moss animals" (*Bryozoa*); crustaceans, which includes crabs, shrimp, isopods, amphipods and barnacles (*Arthropoda*); bivalves, snails, limpets, nudibranchs, octopus, squid and chitons (*Mollusca*); lampshells (*Brachipoda*); sea stars, brittle stars, sea cucumbers, sea urchins, sand dollars and feather stars (*Echinodermata*); and sea squirts and ascideans or tunicates (*Urochordata*).

More than 40 invertebrate species are managed on the Pacific coast. Harvesting is conducted both for commercial and recreational purposes, and methods are specific to the targeted species. Common by-hand harvesting methods include digging, diving, trapping by ring or dip nets; mechanical methods include trawl, seine, jig and limited use of hook and line.

Harvesting patterns also vary greatly from species to species. For instance, the inception of the crab commercial fishery occurred before the turn of the 19th century, with the first recorded landings made in 1885. The crab sport fishery has an equally long history; First Nations' harvests of Dungeness crab precede the discovery of North America by Europeans. Commercial clam fishing began just before the turn of the 20th century, and the B.C. prawn trap fishery began prior to 1914. This contrasts with the euphausiid trawl fishery, which began in the Strait of Georgia in 1970 as an experimental fishery, and the commercial dive fishery for geoducks in B.C., which began coastwide in 1976. Whether the harvest began simply as a means of recreation or for profit, these species have been and will continue to be important to the economy and culture of Canada's west coast.

Geoduck Clam

Background

The geoduck clam (*Panopea abrupta*) occurs from Alaska to the Gulf of California in the Northeastern Pacific Ocean, from the intertidal zone to depths of at least 110 m. It buries itself up to a metre deep in sand, silt, gravel and other soft substrates. The fishery occurs throughout Canada's west coast and is conducted with specialized dive gear.

Geoducks have separate sexes. Spawning occurs annually, primarily from June to July, when waters are warm. Females release from 7–10 million eggs, which develop through several stages in the water column until settling on the bottom within 40–50 days. At a shell length of 2 mm, they burrow into the substrate and can bury to a refuge depth of 60 cm in two years. The end of the burrowing stage coincides with the beginning of annual reproductive activity. Mature sex organs are found in clams between 7 and 107 years old, suggesting that individuals may be capable of reproducing for over a century.

Geoducks are among the longest-lived animals in the world. Growth-ring analysis shows many individuals live for more than 100 years. They grow rapidly in the first 10–15 years, after which time the growth in shell length almost ceases and is replaced by a thickening of the shell and a slow increase in body weight. Geoducks begin to recruit to the fishery at age four and are fully recruited at 12 years.

Fishery Management

The geoduck fishery continues to be one of B.C.'s most valuable fisheries. In 1995, landed value peaked at approximately $42 million (ex-vessel price), but has since declined to about $30 million. In 1999, the wholesale value of geoducks jumped more than 30 per cent to $55.5 million. The product is sold live to Asian markets and the value of the fishery is largely market-driven. The Asian markets favour geoducks with light-coloured, unblemished necks, however, the same price is paid to fishers regardless of quality. Geoducks are harvested individually by divers with the use of a directed water jet. The fishery is conducted throughout the year, but time-area closures occur as a result of paralytic shellfish poison contamination.

Geoducks have been fished commercially in B.C. since 1976. The fishery began in the inside waters (Areas 12–19, 28, 29), expanded to the west coast of Vancouver Island (Areas 21–27) the following year, and to the north coast (Areas 1–11) in 1980. Landings peaked in 1987 at 5,735 tonnes and steadily declined to 1,817 tonnes in 1996 through management actions. Since then, quotas and landings have remained at about the same level.

The fishery was initially unregulated and expanded rapidly until 1979, when limited entry and catch limits were imposed. Licence limitation reduced the fleet to 55 in 1981. Individual vessel quotas were introduced in 1989, along with a three-year rotational fishery, in which only one third of the coast is fished in any one year, but at three times the annual rate. With individual vessel quotas, all landings are monitored by port observers. The costs associated with port validation of vessel landings, on-grounds observer coverage, market sample and biological sample collection and processing, and survey data collection are recovered from the industry.

Geoduck quotas are based on a fixed exploitation rate strategy, which relies on estimates of virgin biomass. Virgin stock biomass for each geoduck bed is calculated as a product of estimates of the bed area mean virgin geoduck density, and mean individual geoduck weight. Annual quotas are determined by applying an annual harvest rate of 1 per cent to the biomass estimate on a bed-by-bed basis. Since 1984, quotas have been based on fisheries and survey data.

Geoduck bed area is measured by digitizing the polygons drawn on reference nautical charts, which are provided by individual fishers as a condition of licence. The accuracy of these estimates is affected by the accuracy of the data supplied by the industry, the interpretation of this information, and the variable imprecision of the nautical charts used.

Estimates of mean geoduck density were initially based on surveys conducted in Washington state and on industry reports. The earliest transect survey designed to measure density was conducted in B.C. in 1992. Since that time, standard surveys of geoduck beds are conducted annually throughout the coast. As the results become available, density estimates used to calculate biomass are modified.

Area-specific mean geoduck weight is determined from market samples. The harvest rate of 1 per cent per year was derived from yield-per-recruit analysis. Pending the analysis of on-going research data designed to examine recruitment and production characteristics and the effect of fishing on recruitment, the harvest rate is maintained at 1 per cent.

Individual geoduck beds are grouped by geoduck management areas. Over time, fewer beds are grouped together and the number of areas has increased in order to spread out fishing effort and reduce the potential for local overharvesting. Based on current estimates of area and density, approximately 9 per cent of the total coastwide bed area of 26,400 hectares is believed to have been overharvested and is now closed to allow recovery.

The commercial fleet has explored and discovered most of the productive grounds in the south coast, whereas new beds are still being discovered in the north coast of B.C.

Outlook

Continued improvement in the estimates of geoduck density and total bed area are anticipated through results of surveys and on-grounds observer reports. The steady decline in quotas seen in the last decade has eased and it is expected that quotas for the near future will remain around the levels set for the 1997 fishery.

Large numbers of geoducks inhabit natural refugia. These include deepwater stocks (divers are limited to depths of less than 20 m), colonies in gravel- or shell-packed substrates from which geoducks are too difficult to extract, individuals considered esthetically inferior and unacceptable to the market, and stocks in contaminated areas and parks. These form a protected breeding pool that may act as a buffer against the pressure of overfishing.

Experimental work on the effects of fishing on recruitment is in progress. Age compositions based on biological samples and reports from fishers indicate that there has been strong recruitment in recent years in geoduck beds over a range of harvest histories. This refutes earlier suggestions that harvesting has a negative effect on recruitment, but further investigation is necessary.

Native Littleneck Clam

Background

Littleneck clams (*Protothaca staminea*) are found from the Aleutian Islands to Baja California Sur, though they are generally abundant only north of Oregon. They inhabit the mid to lower intertidal zone on Canada's west coast, in mixed substrates of gravel, sand and mud. Although occasionally recorded to 10 m depth, there are no significant subtidal populations of littleneck clams in B.C.

Littleneck clams have separate sexes. They mature at between 22 and 35 mm in length, or approximately two to three years of age. In B.C., they spawn from April to October. Larvae are planktonic for three or four weeks before settling in suitable habitat. Adult populations, once settled on one beach, cannot move to another. Although there may be some movement of clams on a beach, distinct growth rates on upper and lower portions of a beach indicate that these movements are relatively limited.

Age is estimated from counts of annual rings on the shell surface. Maximum age in B.C. is 14 years. Growth varies considerably from beach to beach, and between tide levels on a given beach. Growth is rapid to five years of age, and then slows. Littleneck clams can reach legal size (38 mm length) in the Strait of Georgia in three years. Maximum size (70 mm) is reached in 10 years.

Fishery Management

Intertidal clam landings have been recorded since the turn of the century, and clams were important to First Nations peoples long before European contact. The littleneck clam resource currently supports commercial, depuration and recreational harvests, and First Nations food and ceremonial requirements. These fisheries also exploit stocks of Manila clams (*Venerupis philippinarum*) and to a lesser extent, butter clams (*Saxidomus gigantea*).

Licensed commercial clam diggers are required to designate one of six Clam Areas (B–G) they wish to fish each year and then compete for available clams during short intense openings. In 1998, the intertidal clam fishery underwent licence limitation, resulting in a reduction from approximately 2,500 licensed diggers in 1988 to 1,160 eligible participants. Clam harvesters fish during low tides, using rakes or scrapers to turn littleneck clams out of the substrate and collect them by hand.

Several collaborative pilot projects that provide First Nations with communal commercial harvest opportunities on beaches fronting reserves are underway in the Strait of Georgia and on the west coast of Vancouver Island.

Intertidal clam fisheries have been closed in the north coast region since 1963. These closures are the result of concerns regarding water quality and paralytic shellfish poisoning, which, in the absence of monitoring programs, create potential human health risks. A pilot commercial communal fishery occurs near Bella Bella, with special water quality and product monitoring programs.

The depuration fishery utilizes relatively new technology to allow access to product which is marginally contaminated by fecal coliform either from human (sewage or agricultural) or natural sources. Depuration is the process of maintaining live bivalves in purified seawater for a period sufficient to purge them of fecal coliform contamination. Depuration harvests are carried out on marginally contaminated beaches. Depuration opportunities are allocated to certified depuration processing facilities, or jointly to depuration processors and First Nations where beaches fronting reserves are contaminated. Harvests are coordinated by the processors over the permit year. Total allowable catches are determined from assessment surveys carried out by industry or First Nations.

There are no limits on the number of recreational harvesters, but recreational harvests are assumed to be minor relative to commercial harvest levels. Since 1995, recreational fishermen wishing to harvest clams have been required to purchase a Tidal Water Sport Fishing Licence. Recreational and First Nations food, social and ceremonial harvests are open year-round, except for time and area closures due to fecal contamination or paralytic shellfish poisoning.

Commercial clam landings since the 1950s were dominated by butter clams until a shift in market preference increased demand for Manila and native littleneck clams. The shift in market was primarily driven by demand for Manila clams, which are attractive clams that are easily removed from the shell after cooking. Landings of littleneck clams increased dramatically in the early 1980s, averaging 225 tonnes annually from 1980–95, up from a 149-tonne annual average from 1951–79. Recent maximum landings were 465 tonnes in 1990, second only to 631 tonnes in 1972.

Recent landings of littleneck clams are primarily from Johnstone Strait (Clam Area G) and the Strait of Georgia (Areas B–E). Since 1963, most central and north coast areas have been closed to commercial harvest of clams due to chronic paralytic shellfish poisoning and a lack of monitoring programs. The pilot commercial communal fishery in Bella Bella has landed almost exclusively Manila clams.

Information regarding historic levels of effort in B.C. clam fisheries is scarce. Clam harvesters were not required to obtain a separate licence prior to 1989. Age requirements for licences have changed since 1989 (commercial diggers under 16 years of age were not required to have licences from 1990 through 1994). Thus, interpretation of trends in effort is difficult.

Licence limitation has resulted in more days open to digging in each area and increased benefit to individual diggers as available harvest is divided among fewer participants in the fishery.

The commercial fishery is managed primary for Manila clams, using a minimum size limit of 38 mm (which allows clams to spawn at least once before reaching legal size and also applies to littleneck clams), area licensing, and time and area closures. As landings in an area approach recent production levels, managers monitor landings from the fishery for evidence that available legal size stock is becoming depleted. Indicators include increased incidence of sublegal clams, higher proportion of the less desirable littleneck clam in the catch, encroachment into closed areas, decreases in average landing per digger or decreased number of diggers. When managers observe indications that legal stocks are becoming depleted, they close the area.

Depuration harvests are managed more conservatively than other commercial fisheries. In addition to the size limit, total allowable catches are set as a proportion of the estimated legal stock from the most recent assessment survey.

Littlenecks are landed incidentally in intertidal clam fisheries in the Strait of Georgia and on the west coast of Vancouver Island, which are primarily directed at Manila clams. Littleneck landings have accounted for less than 21 per cent of the total steamer clam landings since 1983, and have not exceeded 10 per cent of total steamer landings since 1992. Concerns in the fishery center around Manila clams. Littleneck clams are assumed to be adequately protected by the minimum size limit and decreased fishing pressure due to lesser desirability.

Outlook

There is concern that intensive harvests and repeated digging may affect clam survival and growth rates. The legal size limit, which is based on size of first maturity, also may not provide adequate protection from poor recruitment when harvests remove the majority of legal-sized clams. A number of beaches in the depuration fishery are being harvested under an experimental program that examines stock response to various levels of harvest. These beaches are monitored to develop demographic parameters (natural mortality estimates and recruitment patterns) required for scientifically rigorous assessments of clam populations and further development of management plans.

Additional beaches are lost each year to fecal contamination closures, which may be a result of municipal sewage and stormwater outfalls, faulty septic fields, agricultural run-off, discharge from vessels, or natural sources. Incidence of contaminated bivalves is of concern, both in terms of lost access to a valuable fishery resource, and in terms of potential health hazards and market perception of the B.C. product should illegally harvested contaminated clams make their way to market.

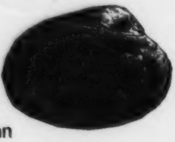
The varnish clam (*Nuttallia obscurata*), introduced into B.C. waters in the early 1990s, is widespread in the Strait of Georgia and present in Barkley Sound. This species is highly invasive, and exhibits habitat preferences similar to littleneck and Manila clams. Preliminary information indicates that varnish clams have commercial potential, and work is underway to develop a commercial fishery for this species. Whether this species will affect littleneck clam productivity through ecological competition is uncertain.

Manila clam

Background

Manila clams (*Venerupis philippinarum*) were inadvertently introduced to B.C. in the 1930s with imported Japanese oyster seed. They quickly spread throughout the Strait of Georgia from Ladysmith Harbour, and north from Barkley Sound on the west coast of Vancouver Island. They currently range from the central coast of B.C. to California, and are found intertidally above the half-tide level in mixed substrates of gravel, sand or mud.

Manila clams have separate sexes and are broadcast spawners, synchronously releasing gametes into the water column, where fertilization occurs. They mature at between 20 and 25 mm in length, or approximately two to three years of age. They spawn from June to September in the Strait of Georgia. Larvae are planktonic for three or four weeks before settling in suitable habitat. Adult populations are closed – once settled on one beach, clams cannot move to another. Although there may be some movement of clams on a beach, distinct growth rates on upper and lower portions of a beach indicate that these movements are relatively limited.



Age is estimated by interpretation and counts of annual rings on the shell surface. Maximum age in B.C. is 14 years. Growth varies considerably from beach to beach, and between tide levels on a given beach. Growth is rapid to five years of age, and then slows. Manila clams can reach legal size (38 mm in length) in the Strait of Georgia in less than four years. Maximum size (75 mm) is reached in 8–10 years.

Because Manila clams live high in the intertidal zone and do not burrow deeply into the sand, they are susceptible to environmentally-induced mortality when frost is driven into the beach by a combination of low air temperatures, night-time low tides and prevailing winds. These "winter kills" can remove significant proportions of the population. Large-scale winter kills were recorded at specific locations in the Strait of Georgia in 1976–77, 1984–85, and 1995–96, and minor kills occur annually.

Fishery Management

The Manila clam resource currently supports commercial, depuration and recreational harvests, and First Nations' food and ceremonial requirements. These fisheries also exploit stocks of native littleneck clams (*Protothaca staminea*) and, to a lesser extent, butter clams (*Saxidomus gigantea*). Manila clams are also cultured on intertidal leases in the Strait of Georgia and the west coast of Vancouver Island. Clam harvesters fish during low tides, using rakes or scrapers to turn Manila clams out of the substrate and collect them by hand.

Licensed commercial clam diggers are required to designate one of six clam Areas (B–G) they wish to fish and then compete for available clams during short, intense openings. In 1998, the intertidal clam fishery underwent licence limitation, resulting in a reduction from approximately 2,500 licensed diggers in 1988 to 1,160 eligible participants.

Several collaborative pilot projects that provide First Nations communal commercial harvest opportunities on beaches fronting reserves are underway in the Strait of Georgia and on the west coast of Vancouver Island.

Intertidal clam fisheries have been closed in the north coast region since 1963. These closures are the result of concerns regarding water quality and paralytic shellfish poisoning, which, in the absence of monitoring programs, create potential human health risks. A pilot commercial communal fishery occurs near Bella Bella, with special water and product quality monitoring programs.

The depuration fishery utilizes relatively new technology to allow access to product which is marginally contaminated by fecal coliform either from human (sewage or agricultural) or natural sources. Depuration is the process of maintaining live bivalves in purified seawater long enough to purge them of contamination. Depuration opportunities are allocated to certified processing facilities, or jointly to depuration processors and First Nations where beaches fronting reserves are contaminated, and harvests are coordinated by the processors over the permit year. Total allowable catches are determined from assessment surveys carried out by industry or First Nations.

There are no limits on the number of recreational harvesters, but such harvests are assumed to be minor relative to commercial harvest levels. Since 1995, recreational fishers who wish to harvest clams have been required to purchase a Tidal Waters Sport Fishing Licence. Recreational and First Nations food, social and ceremonial harvests are open year-round, except for time and area closures due to fecal contamination or paralytic shellfish poisoning.

Commercial clam landings since the 1950s were dominated by butter clams until a shift in market preference in the 1980s increased demand for steamers (Manila and native littleneck clams). The market shift was primarily driven by demand for Manila clams, which are an attractive clam that separates easily from the shell after cooking.

Landings of Manila clams and mixed steamers (which are presumed to be primarily Manila clams) increased dramatically in the early 1980s, averaging 1,668 tonnes between 1980 and 1998, as opposed to 189 tonnes from 1951–79. Manila clam landings decreased after 1988, primarily as a result of area licensing, and time and area closures. In recent years, openings have been reduced in most areas to only a few days per year. Regardless of reduced opportunity, landings increased to 1,557 tonnes in 1994, and have fluctuated between approximately 1,000 and 1,400 tonnes since then. However, these statistics include depuration landings since 1994, representing the revival of operations on some beaches that had been lost to contamination.

Landings of Manila clams are primarily from the Strait of Georgia (Clam Areas B–E) and the west coast of Vancouver Island (Clam Area F). Manila clams are not plentiful in Queen Charlotte Strait (Clam Area G) or the central coast, with the exception of the Bella Bella area.

Information regarding historic levels of effort in B.C. clam fisheries is scarce. Clam harvesters were not required to obtain a separate licence prior to 1989. Age requirements for licences have changed since 1989 (commercial diggers under 16 years of age were not required to have licences from 1990 through 1994), and so interpretation of trends in effort is difficult.

Licence limitation has resulted in fewer open harvesting days in each area and increased benefit to individual diggers as the available harvest is divided among fewer participants in the fishery.

The commercial Manila clam fishery is managed under a 38-mm minimum size limit (which allows clams to spawn at least once before reaching legal size), area licensing, and time and area closures. As landings for an area approach recent production levels, managers monitor landings from the fishery for evidence that available legal size stock is becoming depleted. Indicators include increased incidence of sublegal clams, higher proportion of the less-desirable native littleneck clam in the catch, encroachment into closed areas, decreases in average landing per digger or decreased number of diggers. When managers see evidence that legal stocks are becoming depleted they close the area.

Openings are coordinated to allow opportunities in each clam management area throughout the year, and provide a consistent supply of product to market. Scheduled openings may be suspended or delayed due to the occurrence of hazardous algal blooms.

Depuration harvests are managed more conservatively than other commercial fisheries. In addition to the 38-mm size limit, annual total allowable catches are set as a portion of the estimated legal stock from the most recent assessment survey. Depurators determine when they wish to harvest allocated beaches, unless the area is closed due to paralytic shellfish poisoning.

The recreational fishery does not have a size limit and is managed under a daily bag limit of 75 clams. Catch and effort in recreational and First Nations food and ceremonial harvests are not well documented.

Intertidal clam landings are recorded by Pacific Fisheries Management Area and/or Subarea. Therefore, catch and effort histories for specific beaches are not available. In most areas, accumulated biomass and multiple age groups within the legal portion of the stock have been removed, and fisheries are assumed to be supported primarily by annual recruitment to legal size. Some important beaches in the Strait of Georgia and entire areas of the west coast of Vancouver Island have been closed due to conservation concerns in recent years.

Outlook

There is concern that intensive harvests and repeated digging may affect clam survival and growth rates. The legal size limit, which is based on size of first maturity, also may not provide adequate protection from poor recruitment when harvests remove the majority of legal-sized clams. A number of beaches in the depuration fishery are being harvested under an experimental program that examines stock response to various levels of harvest. These beaches are monitored to develop demographic parameters such as natural mortality estimates and recruitment patterns required for scientifically rigorous assessments of clam populations, and further development of management plans.

Additional beaches are lost each year to fecal contamination closures, which may be a result of municipal sewage and stormwater outfalls, faulty septic fields, agricultural run-off, discharge from vessels, or natural sources. Incidence of contaminated bivalves is of concern, both in terms of lost access to a valuable fishery resource, and in terms of potential health hazards and market perception of B.C. product if illegally harvested, contaminated clams make their way to market.

Market competition with Manila clams from aquaculture and depuration harvests, U.S. product and imported species from Mexico and New Zealand has affected the market price for Manilas from the commercial fishery. Lower prices could result in decreased value from the fishery, even with stable production.

The varnish clam (*Nuttallia obscurata*), introduced into B.C. in the early 1990s, is widespread in the Strait of Georgia and present in Barkley Sound. This species is highly invasive, and exhibits habitat preferences similar to Manila and littleneck clams. On some beaches in the Strait of Georgia, varnish clam populations are equal to Manila clam populations. Preliminary information indicates that varnish clams have commercial potential, and work is underway to develop a commercial fishery for this species. Whether this species will affect Manila clam productivity through ecological competition is uncertain. It is also unknown what effect introducing another intertidal clam species to already competitive markets will have on the value of the Manila clam fishery.

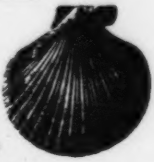
Pink and Spiny Scallops

Background

The pink scallop (*Chlamys rubida*) ranges from Kodiak Island, Alaska to San Diego, California, in water depths of 1–200 m and in water temperatures of 1–17°C, living on relatively soft substrates. Spiny scallops (*C. hastata*) range from the Gulf of Alaska to San Diego, California, in water depths of 2–150 m and in water temperatures of 0–23°C. They usually occur on firm gravel or rocky substrates.

Both species have separate sexes, and both mature at about two years of age, at 25–35 mm shell height. Pink scallops spawn from March to April and again from September to early October; spiny scallops spawn from July to August. Maximum age appeared to be six years in both species. However, recent biological samples indicate that both species may live up to eight or nine years.

Pink and spiny scallops were commercially harvested in B.C. starting in 1982, using divers and small trawl nets. At the end of 1999, concerns about localized over-harvesting, the fact that little is known about overall species distribution and abundance or population structure, and the unknown environmental impacts of the trawl fishery resulted in Fisheries and Oceans Canada closing the commercial fishery. It will remain closed until sufficient information is obtained for biologically-based assessments and an active management system. To collect the necessary data, a number of experimental licences have been issued. Landings from the first year of the experimental fisheries were similar to the last two years of the commercial fisheries, slightly over 100,000 lb.



Fisheries Management

The former commercial fisheries for pink and spiny scallops were concentrated in inshore waters of Areas 13, 14, 17, 18, 20 and 29. Until the closure of the commercial fishery at the end of 1999, divers landed 85 per cent of the commercial catch, mostly from Areas 18 and 19; 80 per cent of the total trawl fishery came from Areas 14 and 20. During the commercial fisheries, a passive management system with unlimited access was applied. The few management controls included area closures and a minimum size limit of 55 mm shell height.

Given the insufficient data to recommend biologically-based management for pink and spiny scallops, more precautionary measures, including new management controls and assessment programs, have been undertaken with the phased approach of experimental fisheries. These new measures include biomass surveys with experimental harvest rates, habitat impact assessments, and collecting biological information for age-structure analysis and mortality estimates.

Paralytic shellfish poisoning and amnesic shellfish poisoning are of particular concern in pink and spiny scallops because, unlike larger scallop species, they are marketed whole in the shell, fresh or frozen. A toxin outbreak monitoring program and precautionary closures limit the risk of exposure.

Outlook

Prior to the 1999 commercial fisheries closure, localized over-harvesting occurred in a few formerly productive areas. Without an active assessment program and management controls in place, over-harvesting was expected to occur in other sub-areas as effort was redirected from those depleted stock areas. However, the experimental fisheries are designed to distribute effort and thus avoid localized depletions. Preliminary results from the experimental trawl fishery indicate minimal bycatch and environmental disturbance due to the unique design of the trawl used in this fishery.

New areas of potentially harvestable scallop concentrations have been identified by both the dive fleet and the trawl fleet. Biomass estimates from these new areas and from areas that were previously heavily harvested will be used to set precautionary harvest levels. In addition, scallop assessment and management areas are being considered as a more effective assessment/management unit than the traditional management areas used in other fisheries. An assessment document reviewing the experimental fisheries will be presented to the Pacific Scientific Advice Review Committee in June 2002 to identify the options of re-opening the commercial fisheries.

Goose Barnacle

Background

The goose barnacle (*Pollicipes polymerus*) ranges from southern Alaska to Baja California on the mid-intertidal zone on exposed or semi-exposed rocky coasts.

Goose barnacles are hermaphroditic (each individual has both sexes). They mature at between 14 and 17 mm rostral-carinal length, at one to three years of age. Spawning is from late April to early October, with peak spawning in July, producing between 475,000 and 950,000 embryos per adult each season. Larvae are planktonic for 30–40 days, and settle in suitable habitat at 0.5-mm length..

Growth is rapid the first year (11–15 mm rostral-carinal length) and then slows to 1–3 mm a year. Maximum size is 45 mm rostral-carinal length, 153 mm peduncle length. Maximum age is unknown. The muscular stalk (peduncle) is analogous to the muscular tail of shrimp, prawns or lobster.

The stock status is unknown, as there are no data available for assessments. However, they are abundant in selected but limited habitats. The impact of harvesting is unknown with respect to sustainability and ecological considerations. The fishery closed on May 31, 1999, due to conservation and environmental concerns. Before it was closed, the commercial fishery was an open-access fishery with no size limits or annual total allowable catch.

Fisheries Management

First Nations have long used goose barnacles as food. Goose barnacles have been commercially harvested sporadically since the 1970s, and continuously since 1985. They are hand harvested with modified cutting and prying tools used to free goose barnacles from their substrates. They are then stored and shipped as live product. No power or mechanical devices, including diving gear, are permitted for harvesting goose barnacles.

Goose barnacles have long been recognized as a delicacy in Spain, Portugal and France. Prior to the fishery closure, the major market for Canadian west coast goose barnacles was Spain, particularly the Barcelona area. The market price in Spain varies with the season and availability from other sources.

When the fishery was active, accessibility to the wave-swept areas of the west coast of Vancouver Island, the central coast, north coast, and the Queen Charlotte Islands, and the logistics of live transport from the harvest areas to the European market limited harvests to a few selected areas. The fishery expanded to the north coast in 1988 and 1989, but shipment of live product proved difficult. There have been no reported landings from the north coast since 1995. From the south coast, reported landings mainly occurred along the west coast of Vancouver Island. Harvesting usually occurred steadily throughout the year. Wet storage of harvested product was permitted prior to shipment of the live product to market.

Before the fishery closed, commercial harvesters of goose barnacles required a category Z–6 licence, in addition to a Fishers Registration Card. Since 1995, recreational fishers have been required to purchase a Tidal Water Sport Fishing Licence for goose barnacles.

Commercial landings, reported from sales-slip data, grew rapidly from 1985 to a peak of 49 tonnes in 1988. From 1989–93, reported landings ranged between 30 and 40 tonnes. This declined to 19 tonnes in 1994, and 7 tonnes in 1995.

In 1988, with the record catch of 49 tonnes, the number of licences peaked at 467. By 1996, this had declined to 56 licences, with only 14 licences reporting landings. The fluctuations in the number of licences and reported landings were related to market conditions. The previous low prices were attributed to lack of suitable and accessible product, and the Spanish retail market.

Conditions of licence included the daily completion of a harvest log with monthly submission to the Fisheries and Oceans Canada Shellfish Data Unit, and the completion of fish slips upon landing product and submission to the Fisheries and Oceans Canada Catch Statistics Unit. The recreational fishing limit is 2 kg per day, with a possession limit of 4 kg.

Goose barnacle landings were previously recorded by Pacific Fishery Management Area and/or Subarea only. Therefore, catch and effort histories cannot be developed from past data. However, information provided on the present harvest log form was sufficiently specific to develop catch and effort histories from specific beds. There were large discrepancies between the fish slip database and the harvest log database. A great deal of anecdotal information existed on unlicensed harvesters and unreported catches from isolated areas.

Until very recently, there were no limits applied in this fishery, as most of the stock was not available for harvest due to inaccessible harvest conditions, difficult logistics in shipping live product, or unsuitable size and quality of product. The lack of suitable and accessible product may be a good indication of localized overfishing. The continued lack of accessibility to suitable product and the price fluctuations in the Spanish retail market indicated that low effort and landings would likely continue. Continued illegal harvest activities may jeopardize this fishery by overharvesting accessible areas, and jeopardize the market by shipping inferior product.

Experienced harvesters indicate that for recruitment of suitable product there is a three-year recovery period following extensive harvest. Feasibility studies conducted for commercial fisheries have shown that following harvest, three to five years are required for recruitment of suitable product. Stock monitoring, area closures, rotational harvesting, and habitat impact assessments will be required to effectively manage a sustainable fishery.

Outlook

Given that there are not sufficient data to recommend biologically based management for goose barnacles, more precautionary measures, including new management controls and assessment programs are being considered. The re-opening and continuation of the goose barnacle fishery must follow the phased approach described in the Pacific Region Policy for New and Developing Fisheries.

Prawns

Background

Prawns (*Pandalus platyceros*) are the largest of the seven commercial species of shrimp in Canada's west coast waters, all belonging to the family Pandalidae. Prawns generally live for four years, starting their lives as males and maturing at one year of age. They function as mature males for two years and then transform into females in the final year of life. This condition is known as protandric hermaphrodism.

Prawns live in rocky habitats, from the intertidal zone to a depth of 487 m, but normal adult habitat is between 70 and 90 m. They are distributed throughout the Northeastern Pacific Ocean, from San Diego, California, to Unalaska Island, Alaska, and in the Northwestern Pacific from the Sea of Japan to the Korea Strait.

Mature prawns breed in the autumn. The female carries fertilized eggs on small appendages of the abdomen known as pleopods or swimmerets, from October to April, at which time the larvae hatch and spend up to three months in the water column before settling on the bottom.

Adult prawns do not migrate to any significant extent and, therefore, there may be hundreds of localized adult stocks. Since trap limitation in 1995, improvements have been made in the geographic coverage of in-season biological sampling, the mean monthly index is being applied in a more conservative fashion, and more timely closures have been implemented in response to stock-assessment recommendations. This management regime is intended to move fishing effort in a timely fashion to prevent localized overfishing. Stocks are believed to be healthy in most coastal areas.

Fishery Management

Prawns in the commercial fishery are caught in traps deployed on long-lines, commonly from 55–90 m on rocky bottoms. The annual prawn catch has been generally increasing since 1980, and in 1996 and 1997 it exceeded 1,700 tonnes. In 1998, recorded catch fell to 1,675 tonnes but was still the third-highest catch on record.

The commercial prawn fishery occurs throughout the B.C. coast. In 1998, 23 per cent of the total catch was reported from northern coastal waters in Areas 1–10 (North Coast Division) and 77 per cent from southern coastal waters in Areas 11–29 (South Coast and Fraser River Divisions). All inshore areas are now considered to be fully subscribed. Opportunity remains to expand the fishery into offshore waters (Areas 101–130).

Most prawns are either landed as whole frozen-at-sea (FAS) product, or as fresh, and then converted to whole frozen product in shore-side processing plants. Frozen product is destined for the Japanese market and has accounted for 90–95 per cent of the total landings in the last three years. Live and fresh product is landed from day vessels operating in southern coastal areas, which are close to local markets.

Historically, the live and fresh product was of higher value, but in 1995, the price paid to fisherman for FAS prawns increased, and their landed value exceeded live and fresh product landed value. By 1997, the whole landed value of FAS prawns product reached a high of $19.80/kg for large FAS prawns. In 1998, however, instability in the Asian market resulted in a price reduction for FAS product, and the value of direct public sales of live and fresh prawns again exceeded FAS product.

The total landed value of the prawn fishery exceeded $26 million in 1996 and 1997. In 1998, the landed value fell to $20 million due to the weakened Japanese market. Landed values continued to decline slightly in 1999 arriving at approximately $17 million.

Recreational fishing occurs near coastal communities. Efforts in recreational prawn fishing is growing. First Nations fishers participate as licence holders in the commercial fishery, as well as occasionally harvesting prawns for food, social, and ceremonial purposes. There is a minor bycatch of prawns in the shrimp trawl fishery.

Licence limitation came into effect for this fishery in 1990. By 1998 there were 253 licences eligible to participate in this fishery. Most licences are now fished every year, either individually or in combination with a second licence. This practice is known as "stacking", an option that was introduced with trap limitation in 1995. In addition to the licence limitation program, a trap limitation program was introduced in 1995, allocating 300 traps per licence. Additional management fees collected as part of this program are used to contract at-sea prawn charter observers, who carry out in-season monitoring of compliance to the trap restrictions. The observers also carry out the in-season monitoring of the catch composition and effort in the fishery. This information is reviewed weekly and analysed to determine necessary closures based on female escapement targets.

The protection of smaller-sized prawns is maintained in the commercial fishery with size limits and the specification of fishery opening dates and locations. The size limit was initially set at a 30-mm carapace length in 1988, and was increased to 33 mm in 1997.

The commercial prawn fishery has been monitored since 1979, using a biological reference point known as the mean monthly index to ensure that female spawning stock is protected. The fishery is closed in an area when the number of spawners falls below a predefined level.

Since trap limitation in 1995, fishers have increased effort and invested capital in vessel upgrades and vessel replacements to achieve greater speed and carrying capacity. Many fishers are now setting their traps several times each day, particularly at the beginning of the season when stocks are strongest. Fortunately, observer sampling has been able to keep pace with this increase. The increasing effort and improved in-season assessment resulted in the fishing season being reduced from 230 days in 1994 to 93 days in 1998. Although managers and stock assessment personnel are confident they are achieving conservation goals, fishers are concerned that their effort in the future may overwhelm the response time of the current management system. They are also concerned for the sustainability of the commercial fishery, but have widely divergent views on the management actions that should be considered.

The recreational fishery in recent years has grown so large in some areas the recreational effort may exceed the commercial effort in areas close to major population centers. Currently, the recreational fishery is not subject to any management closures. However, with this kind of effort severe overfishing can occur and a management strategy could be implemented to address the issue of the fishery's impact on conservation of prawns.

Outlook

The commercial prawn fishery has a strong dependence on the Asian market. Instability in this market in 1998 led to a 30 per cent decline in the landed value of prawns in B.C. In addition, the short seasons of the past few years are generally unsuitable for live and fresh markets, as both markets are easily glutted by short, intense fisheries.

The recreational fishery is expected to grow in more locations as people become more familiar with the fishing techniques. The continuing illegal harvest of prawns is of concern, particularly in areas closed to commercial harvest for conservation purposes.

Shrimp

Background

The shrimp trawl fishery in B.C. catches seven species of shrimp belonging to the family Pandalidae: northern (or spiny) pink shrimp (*Pandalus borealis eous*), smooth pink shrimp (*P. jordani*), sidestripe shrimp (*Pandalopsis dispar*), coonstripe (or dock) shrimp (*Pandalus danae*), humpback shrimp (*P. hypsinotus*), flexed pink shrimp (*P. goniurus*), and prawn (*P. platyceros*).

Pandalid shrimp undergo a change of sex in mid-life, starting out as males and then becoming females in the final year or two of their lives. This is called protandric hermaphrodism. The time spent in each stage varies by species and location. Although this is the general pattern, individuals of some species can bypass the male phase completely and function only as females. These individuals are known as primary females.

Spawning occurs in late autumn or early winter. The females carry developing eggs on appendages known as swimmerets or pleopods until the eggs hatch in spring. The timing of these events varies by species and by area, and is critical information used in establishing the opening of a fishery in order to protect the breeding females long enough to release the eggs.

Shrimp must shed their exoskeleton to grow. As a result, no permanent body structures are retained, and aging the animals using conventional ring-counting techniques is impossible. Instead, an analysis of length data that incorporates the animal's sex and maturity condition is used. Sex and maturity are important factors in the analysis because males and females have different growth patterns. Males continue to grow and moult throughout the year, while females cease moulting while carrying eggs. The abundance of females cannot be extrapolated from age/size composition alone, because some animals can skip the male phase completely. Four years is the maximum age for most species of commercial shrimp in B.C., although most probably live only to age three.

The habitat, behavior and migration of shrimp are important criteria used in stock assessments. Different species generally prefer different habitats, from rocky bottom to mud and sand. Some species prefer to remain on the bottom, while others will move upward into the water column. Coonstripes, humpbacks, and prawns are basically bottom dwellers. Northern pinks and smooth pinks may rise off the bottom at night and will not be as available to bottom-fishing trawl gear. Prawns, meanwhile, may migrate into shallower water. An analysis of catch rate data must incorporate correction factors that will vary by location, gear, species, time of day, and season.

Unlike prawns, which do not tend to move great distances, pink shrimp off the west coast of Vancouver Island have been known to show substantial changes in distribution throughout the year. Stocks of sidestripes in Howe Sound and adjacent areas indicate very limited movement for this species.

Fishery Management

The shrimp fishery off the Pacific Coast developed in earnest in the 1960s with the introduction of trawl bottom gear. Historically, fishing occurred in three major areas of the B.C. coast: the inshore waters of the Strait of Georgia by a fleet composed of small beam trawl vessels; the coastal areas off the north coast inlets, mainly by small local beam trawl vessels; and the west coast of Vancouver Island, where the majority of vessels fished with otter trawls. In 1996, fishing expanded into areas not previously exploited, including the offshore areas of the central coast.

The shrimp trawl fishery on Canada's west coast has traditionally targeted smooth pink, northern pink, and sidestripe shrimp. Humpback, coonstripe, flexed pink and prawns have historically been caught incidentally or in small quantities.

A category S licence is required for participation in this fishery. There are currently 248 eligible S licences, a reduction of one since licence limitations were introduced in 1978. The total catch in the 1995 shrimp trawl fishery was almost double the 1994 landings.

Until 1996, the commercial shrimp trawl fishery was open year-round, with no limitations on catch. That year, the commercial shrimp fleet expanded its efforts into areas that were not historically fished, resulting in unprecedented catches in many areas. As a precautionary measure to protect the stock, a seasonal closure was implemented for the first time on the west coast of Vancouver Island. The main factors responsible for the dramatic increases in landings in 1995 and 1996 were the changes in the groundfish and salmon fisheries that resulted in increased effort on fishing shrimp, the high price offered for shrimp in those two years coinciding with a decline in the Washington and Oregon shrimp fisheries, as well as abundant stocks available to the B.C. fishery. In response, significant changes in the management of the shrimp trawl fishery were implemented in 1997 with the establishment of catch ceilings for most areas, the development of industry-funded programs to monitor catches and a stock assessment program.

The number of vessels in the B.C. shrimp trawl fishery with reported landings increased from 165 vessels in 1994 to 222 in 1996. Historically, the number of active vessels from 1987–94 ranged from 158 to 190. An increase in the number of single licensed vessels, occurring as a result of buy-backs from the salmon industry in 1995, also increased the reliance on the fishery. In 1995, of 249 vessels eligible to fish under the S licence, only six were single licensed vessels. Two years later, 67 of 248 eligible vessels held single licences.

The landed value of the B.C. shrimp trawl fishery ranged from $2.6 million to $4.8 million between 1987 and 1994, reaching a peak of $13.7 million in 1995. The landed value of the 1997 fishery was $5.3 million. Landed values in 1998 and 1999* were $6.6 million and $6.2 million respectively.

A stock assessment program for the shrimp trawl fishery was developed concurrently with the change in management strategy implemented in 1997. Surveys were conducted in selected shrimp areas in 1997 and 1998 to obtain reliable biomass indices of abundance for key stocks. The first year of assessment for most shrimp stocks in B.C. was 1999.

Information used in the assessment of the index areas came from three sources of data: research area-swept surveys, logbooks; and commercial catch sampling. It is suggested that management controls be implemented through a multi-step process in order to meet the objectives of conservation and the development of databases required to understand the stock dynamics. Results from the 1997/98 surveys were used to adjust in-season catch ceilings. These adjustments resulted in both increases and decreases in the preliminary (arbitrary) catch ceilings, depending on the biomass estimates from the surveys. This resulted in reduction of the quota in one area and increases in all the remaining areas. The coast-wide increase in catch ceilings was approximately 635 tonnes of shrimp.

**preliminary estimate*

Until a relationship between biomass indices and shrimp abundance is established, surveys are used in-season to indicate whether an area can sustain fishing pressure greater than, or less than, an initial precautionary area catch ceiling set at the beginning of the year.

The west coast of Vancouver Island has historically been the predominant shrimp fishing grounds, with 80 to 90 per cent of B.C.'s landings taken from the offshore areas. Landings have fluctuated widely, varying between 225 and 5,000 tonnes. Recent survey data from these traditional areas have shown continuous declines.

Management and assessment in the shrimp trawl fishery are complicated by the diversity of shrimp stocks, multiple-species fisheries and varying types of gear. The shrimp species involved occupy varying habitats and ecological niches, and differ in size and value. Although the stock status of B.C. shrimp is yet unknown, assessment programs have been initiated with the goal of developing a biologically based management strategy. There is interest in the development of species-selective and size-selective fishing practices, and in maximizing markets and higher-valued product.

Outlook

There is some concern in this fishery that shrimp stocks cannot support the current size of the commercial fleet. More vessels are now directing more time and effort at shrimp trawling, and sufficient stocks may not exist to support this effort.

Dungeness Crab

Background

The Dungeness crab (*Cancer magister*) is found from California to Alaska, generally on sandy bottoms less than 50 m deep subject to moderate to strong currents. Dungeness crabs are the most important species of crab harvested in B.C. and are exploited by commercial, aboriginal and recreational fishers coast-wide. Major crab fishing areas include Hecate Strait, McIntyre Bay, the Fraser River delta, the Skeena River estuary and waters off Tofino on the west coast of Vancouver Island. This report focuses on crab stocks in Hecate Strait and Dixon Entrance (Licence Area A).

Crabs grow by producing a new shell underneath the old one, a process called moulting. Once the old shell is cast off the new shell quickly swells with water by 20 to 30 per cent. For the first few weeks, the new shell is soft and easily damaged, and the crab is highly vulnerable to natural predation, or to injury or death as a result of trapping and handling. It requires two months or more for the new shell to completely harden and fill with meat. Smaller crabs may moult several times a year while large crabs may only moult once in two years. Moulting generally takes place in late spring.

Management in all Pacific coast crab fisheries focuses on reducing mortality of undersized, female, soft-shelled and juvenile crabs as a means of ensuring reproductive potential. To date, no relationship has been described between stock size and recruitment. At low to moderate effort levels, the highly selective trap fishery does not seriously effect upcoming generations of small crabs. Whether the current high levels of effort will affect long-term stock dynamics on the north coast is unknown. Healthy crab stocks remain on the south coast, despite intensive fisheries over the past several decades.

Fishery Management

North coast Dungeness crab stocks are probably composed of two or more component populations that interact to some extent. These include populations in Dixon Entrance, (Naden Harbour, Virago Sound and McIntyre Bay) and in Hecate Strait. This area has supported the major crab fishery in B.C. since 1993, but historically has shown periods of low stock abundance interspersed with relatively shorter periods of extremely high abundance. Fluctuations are unpredictable, although they appear less pronounced in Dixon Entrance.

The crab fishery on the north coast began in 1920 in Naden Harbour, at the north end of Graham Island, and would have been impracticable if not for the establishment there of the first crab cannery in Canada. With development of the circular trap in the late 1930s, the fishery was extended, first to adjacent Virago Sound and McIntyre Bay (Dixon Entrance) and, in 1946, to Hecate Strait. Until the 1950s, nearly all the catch was canned, but after the Second World War markets developed for fresh-cooked and live crabs. Currently, crabs are shipped live to world markets, or processed and sold fresh-cooked or as shelled meat. The U.S. is the major market. Ex-vessel price in 1997 was $7.44 per kg, with an average live weight of 0.79 kg per crab.

Only male crabs above the regulated minimum shell width of 165 mm are retained by the fishery. Commercial harvest in Area A is primarily by circular traps constructed of a heavy steel frame between 80 and 110 cm in diameter and 20 to 35 cm deep, covered with stainless steel mesh. The traps are baited and usually have two or more entrance tunnels, triggered to prevent escape of large crabs. By regulation, the traps must have an escape port for undersize crabs, and be equipped with a biodegradable device to prevent traps from continuing to fish if lost. As of 1998, traps must be individually buoyed. In this area, traps are hauled every 3–14 days, although the incidence of soak times exceeding the 14-day maximum has increased. Open, mesh-covered rings are the only gear allowed in the Naden Harbour fishery. These are pulled every one to several hours. Crab vessels range from 5–25 m in length and may deploy between 100 and 1,500 traps, depending on vessel size and fishing conditions.

In 1997, crab fishers were required to select one of five licence areas in the province to fish for a trial period of three years. Reselection for one of seven licence areas will be for another three-year period commencing in 2000. The number of commercial licences was limited to 223 in 1991, of which 51 currently fish Area A. Recreational and aboriginal harvest is by trap, ring, dip-net or scuba dive gear. A personal fishing licence or band licence is required and the minimum catch size limit of 165-mm shell width also applies.

Commercial effort has increased significantly over the last decade in this and other invertebrate fisheries, owing to development of new markets, increased value for product, improved harvest technology, and reduced opportunities in finfish fisheries. The high biomass of crabs on the north coast from 1993 to 1996 attracted many fishers from other licence areas and has encouraged over-capitalization.

High variability in Area A crab stocks has been documented over the past 50 years with low abundance levels predominating. The causes of these fluctuations are unknown, although natural forces are suspected. Currently the north coast crab population is shrinking, whereas prices for landed crabs have risen. As a result, fishers have tried to maintain catches by increasing trap inventories, fishing in unsafe conditions, and landing soft crabs. The unprecedented effort levels may be threatening an already declining resource.

Recent management actions are largely a response to these high effort levels. A spring soft-shell closure for Hecate Strait implemented in 1996 and extended in 1997 and 1998 was added to the closure in place for McIntyre Bay since 1958. Trap limitation as a means of reducing effort has been discussed, but it has been rejected by fishers in the area owing to disagreement over equitable trap allocations, and the high levels of enforcement required to ensure compliance over such a vast area. An additional winter closure was imposed in 1998 as an alternative to trap limitation.

Recreational fishing effort directed toward north coast crabs has also increased due to improved access, an increase in the number of fishing lodges and a general increase in tourism.

Gear theft, trap raiding, and other illegal fishing activities have become problems with increasing competition for a declining resource. A major concern with large individual trap inventories is that, due to weather or other problems, it may not be possible to tend all traps within the regulation two-week interval, which results in crab mortality through confinement and cannibalism, and a subsequent loss to the fishery. There is also growing concern over the impact on other crab fisheries if a large number of Area A licence holders elects to change areas in the year 2000.

McIntyre Bay experiences less inter-annual variation in landings than adjacent Hecate Strait. The two areas appear to have separate stock dynamics, although migration of crabs from McIntyre Bay to Hecate Strait has been documented. This may be in response to lower stock densities in Hecate Strait. Some parts of the strait show a stock structure similar to that of intensively exploited stocks on the south coast, where nearly all legal-sized crabs are removed in a given fishing season. Under these conditions, the fishery is sustained mostly by one year-class of crabs and is therefore highly sensitive to natural variation in crab recruitment. Landings from the Hecate Strait component of Area A appear to be naturally unstable. High effort levels may further destabilize this fishery by removing other, larger year-classes of crabs normally present in this fishery. The economics of pursuing this fishery may prevent effort levels from increasing further.

Outlook

The commercial fishery in Area A is probably oversubscribed for the current crab biomass. Except for 1996, catches have been declining steadily since 1993 and are expected to continue to decline in the near future. With changing technology and economics, and long-term changes in climate, it is uncertain at what level this fishery can be sustained. Historic records suggest that a return to higher abundance levels is likely, but the timing and magnitude are unpredictable based on our present knowledge of recruitment mechanisms for this area.

Opal Squid

Background

Opal squid (*Loligo opalescens*), also called market squid, are found from the southern Gulf of Alaska (50°N) to southern California (25°N). They are common in nearshore and inshore waters throughout their range.

Mating and spawning can be separate events for opal squid. The males pass sperm packets to the females during elaborate courtship behaviours. The female stores the sperm until her eggs mature. On Canada's west coast, spawning generally occurs between December and September, with two major peaks of activity in March and July. There is a general pattern of winter spawning in the Strait of Georgia and Queen Charlotte Strait, with summer spawning near Victoria and on the west coast of Vancouver Island. Spawning squid form large aggregations in sheltered bays and inlets, where they attach elongated, transparent egg masses to solid objects. Adult squid die after spawning.

In B.C., eggs hatch after two or three months, depending on the temperature. Young squid grow rapidly, and move to the bottom at about 5 cm total length. Opal squid can grow to approximately 35 cm total length, but rarely exceed 20 cm in B.C. Males grow larger than females. Squid may become mature at one year, and live less than two years.

Opal squid feed on small fish, krill and other plankton, and on smaller squid. They, in turn, are preyed upon by salmon and numerous other fish species, marine mammals and sea birds.

Fishery Management

In B.C., opal squid are fished primarily as bait for the sablefish, crab and halibut fisheries. There is interest in marketing B.C. squid as a food product. However, the food market is very competitive, and demand is currently filled by squid from California and China. Opal squid are primarily fished with seines in B.C., although the use of dipnets, frame nets and jigs are allowed. Squid are attracted to the vessel at night by bright lights, and a seine set around the aggregated squid.

Opal squid landings are highly variable from year to year. Record landings were reported in 1994, and have decreased dramatically since. The west coast of Vancouver Island, primarily Area 23, has traditionally accounted for the greatest share of B.C. opal squid landings. In 1995, 1997 and 1998, however, the north coast (Areas 1–10) accounted for the majority of coastwide landings. This is due not only to an increase in landings from the north coast, but also to a decrease in landings from the west coast of Vancouver Island. It is not known whether the change in the pattern of landings is due to a change in squid distribution, or other factors.

Preliminary reported landing of squid in 1998 were 23 tonnes. The 10-year annual average (1989–1998) was 57 tonnes. The landings fluctuated greatly in that time with a high of 116 tonnes in 1994 and a low of 5.9 tonnes in 1997. The total landed value of the opal squid fishery was $44,000 in 1998.

The number of vessels purchasing squid licences increased from 46 in 1994 to 107 in 1996. At the same time, however, the number of vessels reporting landings only increased from seven to 15. Fifty-five licences were issued in 1997 and this reduced to 35 in 1999 (as of September 30). The number of vessels reporting landings in 1998 was seven from logbooks and four from fish slips.

Catch and effort are likely under-reported in the squid fishery. Since the main market for squid is for bait, a considerable portion of the catch may be used in other fisheries, or bartered to other fishers, and so would not be reported on sales slips. The recreational fishery is limited to only a few sports fishers who use squid for personal consumption. Aggregations of sufficient abundance to be effectively fished are uncommon, and it is difficult to predict when and where these aggregations may appear.

As with most squid, opal populations are characterized by highly variable recruitment and erratic variation in annual abundance. As opal squid live less than two years, population size is primarily determined by annual recruitment. Although recruitment cannot be predicted with any certainty, there is some evidence from California of low recruitment in years of cooler water temperatures.

The stock status of opal squid in B.C. is unknown. With the exception of collecting harvest logbook information and ensuring that logbook data is available, there are no directed assessment programs. Few vessels report landings of squid in B.C., relative to the number of licences purchased. Fishers may be purchasing squid licences for speculative purposes, as this fishery is one of the few on the west coast not under licence limitation.

Outlook

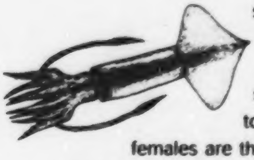
Because B.C. is near the northern limit of distribution of opal squid, population levels are expected to be more variable than in the centre of the species abundance. It is not known whether sufficient stocks would be available annually to support a larger fishery than currently exists in B.C.

Fishing with small-mesh seines has potential for bycatch of juvenile herring and salmonids. For this reason the coast is closed to squid fishing year-round, and specific areas are opened upon request, after managers have assessed the potential for bycatch problems. With the exception of bycatch concerns, opal squid fisheries in B.C. are not actively managed at this time.

Neon Flying Squid

Background

Neon flying squid (*Ommastrephes bartrami*) are large oceanic squid found in the Pacific, Atlantic and Indian oceans. In the North Pacific, they spawn in subtropical waters in the winter, and migrate northward to near the subarctic boundary to feed in the summer and fall. Flying squid generally aggregate near cold-water fronts when feeding near the surface at night and descend to depths greater than 300 m during the day. Flying squid are found in or near B.C. waters from July to September.



Mating and spawning are separate acts. Males mature earlier in the season, and at a smaller size, than females. Males pass spermatophores to females, which are stored in the mantle cavity until the female ripens and spawns. Egg masses are likely spawned in midwater. Fecundity has been estimated at 350,000 to 3.6 million eggs per female, depending on size. Both males and females are thought to die soon after spawning. Larvae are pelagic and grow quickly during the northward migration.

Flying squid live for approximately a year, during which growth is extremely rapid. Researchers have proposed varied combinations of spawning cohorts, and some suggest that the eastern and western North Pacific each have separate stocks. Females grow to 60 cm in mantle length and weigh 5.3 kg, while males are somewhat smaller.

Neon flying squid eat small fish and squid, including smaller individuals of the same species. In turn, flying squid serve as prey for swordfish, marlins, sharks, tunas, marine mammals and seabirds.

As this is a new fishery, little information is available on stock size, biological characteristics or fisheries interactions. The emphasis of current research is on development of catch, effort, bycatch and biological data to monitor fishery performance and develop methods to assess stock status and responses of stocks to fishing.

Fishery Management

Neon flying squid were the target species of Asian driftnet fisheries in the North Pacific from the late 1970s until the early 1990s. Experimental fisheries using driftnets and automated jigging machines between 1979 and 1991 indicated that fishable aggregations of flying squid were available in or near B.C. waters in the late summer and fall.

Exploratory jig fishing for flying squid was undertaken in B.C. in 1996 via a partnership arrangement between industry and the federal and provincial governments. The objective of the agreement was to assess the feasibility of an automated jig fishery off the B.C. coast, both inside and outside of Canada's 200-mile fisheries conservation zone.

Fishers are given authority to fish under a scientific licence, and a licence to fish or transship fish in waters other than Canadian fisheries waters. Eligible vessels must be equipped with automated jigging machinery, high-wattage lighting and an at-sea processing and storage capacity, and be capable of high-seas trips of at least three weeks. Ten licences were approved in 1996, and this was increased to 20 in 1997 and 1998. Three other oceanic squid species were added to the pilot fishery in 1997: the schoolmaster gonate squid (*Berryteuthis magister*), the eight-armed squid (*Gonatopsis borealis*), and the boreal clubhook squid (*Onychoteuthis borealijaponica*).

Relatively few licences were actively fished during the first three years of the pilot fishery. This is a reflection of many licence-eligible vessels continued involvement in traditional fishing opportunities, such as groundfish quotas and large Fraser River sockeye abundance in 1997. Catch rates increased in 1998, but no fishing occurred after October 1, due to inclement weather.

Vessels participating in the pilot fishery report catch, effort, location, oceanographic and weather information on harvest logbooks. Verified landings of various products (mantles, tentacles, wings) which are processed, packed and frozen at sea are converted to whole squid weights using conversion factors determined by observers.

Effort is measured in jig-hours. Each double-spooled machine has two jigging lines, each usually equipped with 10–20 jigs per line. Thus, a vessel operating three machines rigged with 20 jigs per line for one hour expends 120 jig-hours of effort.

Outlook

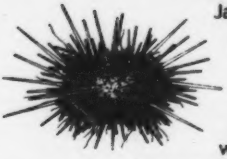
The potential of this fishery remains unproven. Some fishers are beginning to recognize oceanic conditions and acoustic information that may be correlated with squid abundance. Experimentation with underwater lighting and daytime fishing in 1998 led to the highest production in the brief history of the fishery. Further development of these techniques and increased effort in the fishery will likely continue to increase production.

Red Sea Urchin

Background

The red sea urchin (*Strongylocentrotus franciscanus*) is found from Baja California to Alaska, and from the Aleutian Islands to Hokkaido Island, Japan. The largest of five species of sea urchins occurring on Canada's west coast, the red urchin is usually found on rocky substrates in shallow water areas of moderate to strong currents, typically from the intertidal zones to depths of 50 ms, although some individuals occur as deep as 125 m.

Red sea urchins have separate sexes, maturing with shells or "tests" of about 50 mm in diameter, and recruit into the fishery at 100-mm test diameter. Reproduction occurs annually with timing of the spawning season varying from March to September, depending on local environmental conditions such as food availability and temperature. Gonads increase in size usually from September to January. Mature males and females release eggs and sperm into the water and fertilization success will depend on the local density of adults and dilution of gametes. The larvae are planktonic for six to nine weeks prior to settlement on suitable habitat. Juvenile (tests of 4–50 mm) abundance is usually highest when associated with the spine canopy of adults as a refuge from predators. This juvenile-adult association may be important to the recruitment success of juveniles to legal size.



Red sea urchins are harvested by divers and delivered fresh to processing plants where the roe is extracted, treated and sold in Japan and North American markets as uni. Yields of roe from whole sea urchins range from 5–15 per cent. Food availability in the wild is an important factor in determining the quality of red sea urchin roe for the market.

Fishery Management

The red sea urchin has been the subject of a commercial diving fishery in B.C. since the 1970s. Annual landings began to increase rapidly in the early 1980s for the south coast of B.C. and the late 1980s for the north coast, but after 1992 landings were reduced and stabilized by quotas. The total annual landed value has generally increased throughout the red sea urchin fishery to $11.4 million by 1996. In 1999, there were 110 licenced vessels with a coastwide quota of 5,601.6 tonnes, 19.1 per cent allocated to the south coast and 80.9 per cent allocated to the north coast of B.C.

Currently the main management tools in the red sea urchin fishery include a minimum test diameter of 100 mm to allow about three to six spawning years for red sea urchin prior to harvest; a quota system to provide a conservative fixed exploitation rate of 2–3 per cent of estimated biomass; limited licence entry; and an Individual Quota program in which total quota is divided equally among licences. Industry funds management and research through fees to association members. It also contracts independent harvest port validators for the Individual Quota program, an on-grounds monitor to record fishing vessel activity and beds fished, as well as vessels and divers for surveys for biomass estimation and other research activities.

In recent years, annual fishery updates and assessments have been prepared. Quotas are estimated from a modified surplus production model, which provides for a 2–3 per cent annual rate of exploitation of estimated biomass of recruited red sea urchins. Biomass is calculated for each statistical area as the product of the estimated average weight and density of urchins per square metre (from surveys) and bed areas.

Commercial bed areas of red sea urchins were indicated on charts or diagrams provided by fishers with their harvest logbooks throughout B.C. during 1982–96. The detailed beds were outlined on hydrographic charts according to the logbook data, digitized and then areas were estimated. Density and weight estimates were initially based on a few surveys in the south coast of B.C. conducted between 1976 and 1984. Surveys to estimate abundance in the north coast of B.C. were conducted more frequently than in the south coast from 1993–98.

The commercial fleet has discovered most of the red sea urchin productive beds in B.C., although there are a few beds in the north coast that are closed due to overfishing or depletion by sea otters. There are also a few beds that are not fished due to high densities and poor gonad quality.

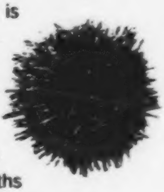
Outlook

Improvement in red sea urchin biomass estimates, natural mortality and understanding stock and recruitment relationships are anticipated through surveys and on-grounds observer reports. A long-term strategy is presently being developed that addresses a request by industry to reduce the minimum legal size limit to better meet market demands for the best quality gonad, and incorporates adaptive management methods for sustainable harvests while maintaining a precautionary approach to management. Sea otter populations are expanding in B.C. and may become a major mortality agent of red sea urchin populations in the future. Currently there are no management plans to restrict sea otter populations as the sea otter is considered an endangered species in B.C.

Green Sea Urchin

Background

Green sea urchins (*Strongylocentrotus droebachiensis*) are members of the phylum Echinodermata, which also includes sea stars and sea cucumbers. Green urchins occur on the Pacific coast of North America from Alaska to northern Washington, generally in intertidal locations and to depths of more than 140 m. They tend to have rather patchy distributions, and appear to be more mobile than the red sea urchin (Strongylocentrotus franciscanus), with which they are often found. It is suspected that green urchins may undertake some form of seasonal deep-shallow migration or movements.



Green sea urchins reach a maximum shell or "test" diameter of slightly greater than 100 mm on the Pacific coast. In Alaska they spawn at test diameters of 45–50 mm, and in B.C. the spawning period generally occurs from February to March. The larvae are planktonic for at least two months before settling to the bottom. Green urchin growth rates vary considerably depending on food availability, with rates of 10 mm per year or more recorded in the Strait of Georgia, B.C., and in Alaska. Under food-limited conditions, growth rates as low as 1–2 mm per year have been recorded for green urchins in the northwest Atlantic.

Fishery Management

The fishery for green sea urchins is a roe fishery, with principal markets in Asia. Only hand-picking by divers is permitted. The fishery is generally conducted during winter, when roe quality, quantity and market prices tend to be highest. The factors producing high-quality roe are unclear, and quality can vary significantly within and among areas. The present management system for green sea urchins in the Pacific Region consists of area quotas and closures, a minimum size limit, and individual licence quotas. Although the fishery is relatively small – landed values from October 1997 to March 1998 were $895,000 – it is an important component of the echinoderm dive fisheries in B.C., which include red sea urchins and sea cucumbers.

The commercial fishery for green sea urchins in B.C. started in 1987. Sporadic catches occurred throughout the year in the early fishery, but subsequently focused on the winter due to good roe quality and the best market prices. Data compilations and analyses are therefore expressed on a "fishing season" basis, defined as October to March and designated with the year for October (i.e. the October 1997 to March 1998 fishing season is designated 1997). Landings peaked in winter 1992 at 978 tonnes, with a value of $4.5 million. The subsequent decline in landings was in part due to management actions, implemented because of conservation concerns resulting from the explosion of effort and catch, and the lack of a detailed resource assessment. Landings since 1995 have been about 150 tonnes. The majority of landings have come from southern B.C. waters because of better roe quality and proximity to processing plants.

A minimum test diameter of 55 mm was established in 1988 to allow green urchins to spawn at least once, and because of market preferences for larger animals. The number of licences was capped in 1991, and has remained at 49 since 1993. An arbitrary total allowable catch of 449 tonnes was established for the south coast in 1994, as a result of conservation concerns. The first formal assessment of green sea urchins in the Pacific Region occurred in 1995. It recommended restricting fishing to the historical core areas (all in the south coast), leading to two principal fishing regions: Queen Charlotte Strait (Areas 11–13) and the Gulf Islands-Victoria (Areas 17–20, 28). Also in 1995, a formal Individual Quota system was implemented with validation at designated landing ports. In 1996 and 1997, the total allowable catch was set at 166 tonnes (3.4 tonnes per licence) within the identified core fishing areas.

Logbook records of fishing activities are required as a condition of licence. These records are used to calculate the trend in catch per unit of effort by management area. Catch per unit of effort declined from the beginning of the fishery, but has been increasing since 1993. These catch and effort data are then used in a surplus production model to estimate the maximum sustainable yield of green sea urchins from the available core fishing areas. In the Queen Charlotte Strait and Johnstone Strait region the maximum sustainable yield was estimated to be 480 tonnes, and for the Gulf Islands-Victoria region, about 100 tonnes. Total allowable catches were set in the range of 25–50 per cent of the estimated maximum sustainable yield to account for uncertainties in the input data and the assumptions of the surplus production model.

Two important questions arise from the assessment of green sea urchins in the

Pacific Region. First, what is the productivity (recruitment, growth, mortality) of green sea urchins in B.C. waters? Second, how can the abundance of green sea urchins in the core fishing areas, the abundance of legal size urchins (55-mm), and the proportion of legal-sized urchins which have high-quality roe be corroborated? To examine the latter question, Fisheries and Oceans Canada, the West Coast Green Urchin Association and local First Nations have embarked on a series of fishery-independent surveys in key fishing locations in Queen Charlotte Strait (Area 12) and the Gulf Islands (Area 18). These surveys examine green sea urchin distribution, abundance, biology and relationships with algae and bottom type, as well as estimate natural and fishing mortalities, exploitation rates, and general growth rates in the surveyed areas to help improve the assessment of green sea urchin resources.

Outlook

The explosive increases in effort and landings of green sea urchins that occurred in the early 1990s are typical of newly developing fisheries and appear to have been restrained. Both landings and the annual catch-per-unit of effort have stabilized since 1995, and the Pacific Fishery Management Plan for green sea urchins now offers quota projections two years in advance. However, the fishery has been reduced to a small but important seasonal component of a suite of echinoderm dive fisheries. There is limited potential for major expansion of this fishery, unless the productive capacity of urchins in those areas presently closed to fishing, principally the west coast of Vancouver Island and most of the central and northern B.C. coast, is proven to be sustainable in the presence of fishing. A small quota was allocated for the north coast of B.C. in 1998 as a result of exploratory surveys in this area.

In general, green sea urchin populations in the Queen Charlotte Strait-Johnstone Strait region appear to be rebuilding and recently they experienced a significant recruitment pulse. In contrast, green urchin populations in the southern Strait of Georgia appear to remain under pressure, and consequently the fishery in these areas has been severely curtailed pending surveys to evaluate their population status.

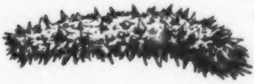
The collaborative multi-agency surveys are key to corroborating estimates of green urchin biomass and impacts of fishing, and identifying natural fluctuations in biological characteristics. Such joint work is crucial for building a sustainable fishery for green sea urchins on Canada's west coast.

Giant Red Sea Cucumber

Background

The giant red or California sea cucumber (*Parastichopus californicus*) is the largest of approximately 30 sea cucumber species on Canada's west coast and the only one that is commercially harvested. The species ranges from the Gulf of Alaska to southern

California, in water depths from the intertidal to 250 m. Sea cucumbers occupy the sea bed in a wide variety of substrate and current regimes, but are most abundant in areas of moderate current on cobbles, boulders or crevassed bedrock. Individuals have limited mobility but can travel up to 4 m per day while feeding and are reputed to undertake seasonal migrations to different depths.



Sea cucumbers have separate sexes, and spawning occurs from spring through summer. Eggs and sperm are released directly into the water and the developing larvae remain planktonic for two to four months. Juveniles grow from 0.25 mm at settlement to approximately one centimetre in one year and to 4–10 cm at the end of two years. During this early life-stage, they have been observed attached to the underside of rocks and in mats of stringy red algae in calm bays, although juveniles have been reported in many different habitats. Adult populations tend to be uniform in size and rarely contain individuals less than 15 cm in length. Age at recruitment to the fishery is thought to be at least four years, since year-classes can be distinguished through analysis of length frequency data for only the first three years.

Sea cucumbers cannot be aged, and so information on mortality and growth rates, age at sexual maturity and longevity is unknown. The body shape is plastic, and hence measurements of body dimensions are difficult to obtain. Furthermore, the animals undergo annual fluctuations in body mass, skin thickness and muscle weight from their yearly cycle of re-absorbing and regenerating their internal organs.

Initial results from surveys conducted in various areas of the coast indicate that sea cucumber densities vary according to habitat (e.g. inlets compared with channels) but are consistently higher than the conservative estimate of density used for the open individual quota fishery. Although there are many unanswered questions regarding the productivity of sea cucumbers in different habitat regimes and their response to harvesting pressure, it seems likely that this fishery has good potential for expansion.

Fishery Management

The annual sea cucumber fishery occurs for about three weeks during the autumn or winter months, when the muscle is generally at its best and the animals have no internal organs. Individual animals are hand-picked from the substrate by scuba divers and taken on board a vessel, where they are cut open longitudinally to remove any viscera and internal fluids in a process called "splitting." The market for the muscle strips and dried skins and is primarily in China, although there is also a small domestic market. The annual landed value of sea cucumbers is just over $1 million.

Commercial exploitation of sea cucumbers began in 1971, when the first landings were recorded. The category C licensed fishery began on an experimental basis in 1980 and expanded rapidly, with annual landings exceeding 1,900 tonnes round weight (700 tonnes split weight) in 1988. Area closures and arbitrary precautionary regional quotas were first implemented in 1986. This did little to limit the fishery, since landings and the number of licences issued continued to increase and quota over-runs were common. This, along with concerns stemming from declining catch per unit effort in some areas, led to arbitrary quota reductions in 1989, the implementation of licence limitation in 1991 and further quota reductions in 1993. From 1993–96, a three-year rotation was introduced in the south coast to allow for recovery of harvested areas for a two-year period between harvests. A rotational fishery is no longer used. Currently, 85 licences are eligible for participation in the fishery. With the introduction of a pilot Individual Quota program in 1995, which required the validation of all landings, quotas were no longer exceeded.

Fishing was initially permitted in south coast areas only (Areas 12–27) and the majority of landings were taken in the Strait of Georgia (Areas 13–20) until 1987. The north coast was opened in 1986 with a quota of 500 tonnes round weight, although fishing did not occur there until 1987. Landings of sea cucumbers have since been recorded from all management areas, with the exception of north and west Queen Charlotte Islands (Areas 1 and 2W), which are the most remote areas on the coast. The central and north coast (Areas 3–10) currently supports about 80 per cent of the

Summary of sea cucumber landings and value (1980–1999)
as reported on Fish Slips and Validation & Harvest Logs

Year	Landings		Landed value
	Round tonnes	Split tonnes[1]	$
1980	–	7.3	–
1981	–	9.9	–
1982	–	1.8	–
1983	–	193.0	–
1984	–	41.4	22,000
1985	–	126.7	94,000
1986	786	287.9	236,000
1987	1,722	630.8	768,000
1988	1,922	704.0	984,000
1989	1,144	419.0	977,000
1990	870	318.7	1,167,000
1991	1,340	490.8	1,029,000
1992	–	521.0	1,363,000
1993	–	298.0	982,000
1994 [2,3,4]	–	196.0	976,000
1995 [2]	–	217.3	956,000
1996	–	240.7	688,000
1997	–	227.4	780,000
1998	–	276.2	1,073,000
1999	–	347.8	N/A

[1] *Data from harvest logs* [2] *Data incomplete*

[3] *Quota was reduced by 27.5 tonnes split weight due to overages in the 1992 Inside Waters fishery*

[4] *A reported 20,255 lbs were spoiled and dumped – it is not known if they are included in this landing record.*

Source: Pacific Region Integrated Fish Management Plan. Sea Cucumber, Oct. 1, 2000 – Sept. 30, 2001 fishery. The total allowable catch (TAC) has increased incrementally since 1998. The coastwide commercial TAC in 1998 was 275.7 tonnes (split weight) as compared to 370.1 tonnes TAC in the 2000-01 commercial fishing season.

Although sea cucumbers have been harvested for more than 20 years, little biological information is available upon which to base quotas and harvest practices. The fishery was therefore incorporated into the "phased approach" described in the Pacific Region Policy for New and Developing Fisheries. Following a review of existing biological and fishery information for P. californicus in B.C. and elsewhere, a framework was designed for an experimental fishery structured to provide data on stock abundance and on the response of the populations to various levels of exploitation.

This framework was developed into an adaptive management plan which was implemented for the 1997 sea cucumber fishery. Under this plan, the existing arbitrary quota of 233 tonnes split weight is maintained in static, non-contiguous areas that equal about 25 per cent of the B.C. coastline. The quota was justified over this proportion of the coast by assuming a density of 2.5 sea cucumbers per metre of shoreline, an exploitation rate of 4.2 per cent and a mean individual weight ranging from 263–327 g, depending on the area. This estimate of density is the minimum of all lower 90 per cent confidence limits from all large-scale surveys conducted in southeast Alaska, and is considered to be very conservative. The exploitation rate is the most conservative of estimates used in Alaska and Washington's sea cucumber fisheries. Mean weight estimates are from biological sampling of harvested product. The management plan allows for abundance surveys to be undertaken in the open areas to defend potential quota increases. Revised density estimates ranging from 6.6 to 11.9 sea cucumbers per metre of shoreline were obtained from surveys in three subareas in Area 7, which led to a quota increase of 42 tonnes.

An additional 25 per cent of the B.C. coastline is designated for experimental fishing, designed to test the effects of varying exploitation rates on sea cucumber populations. These experiments include a pre-fishery survey in each of five 10-km sites, followed by harvest at 0 per cent (control) and 2, 4, 8 and 16 per cent exploitation rates. These rates bracket the current 4.2 per cent exploitation rate. To date, three experimental fisheries are underway; one in a mixed archipelago and channel habitat, one in a straight deep-sided inlet and one in a straight deep-sided channel habitat. Surveys and experimental fisheries in these locations, and others in the future, will continue for at least 10 years or until negative impacts are noticeable. Industry participation is key to the project success, and Fisheries and Oceans Canada requires, and has the commitment from the harvesters association for ongoing monitoring of experimental sites.

The remaining 50 per cent of the B.C. coastline is closed to commercial harvest of sea cucumbers until sufficient information has been gathered that will allow biologically based quotas and management practices. This is expected to take at least 10 years.

Harvesters of sea cucumbers initially targeted dense populations that were close to port and protected from extreme exposure. At that time, researchers and managers felt that only a small proportion of the stock was being harvested and that many sea cucumbers were left untouched in harvesting areas. The distribution of fishing effort has since expanded to more remote northern areas, but fishers still generally target protected bays with gentle slopes and soft substrate where the animals are easily visible. While this practice results in extensive areas that are essentially free of harvesting pressure, it also leads to the depletion of stocks where fishing has occurred. The effects of localized depletion of sea cucumber populations and the time required for recovery from depletion are not fully understood. For some sea cucumber populations, there is little evidence of decreased abundance even after very heavy fishing pressure. For other heavily-fished populations, survey results indicate very low densities after many years of fishery closure. Evidence from recent scientific studies and from fishers' observations indicate that different habitat regimes support different productivity levels.

Sea cucumber populations extend below safe diving depths, where harvesting is unlikely. The existence of deep-water stocks of sea cucumbers is of uncertain advantage, however. Their reproductive potential may be lower than animals in shallower water, since they are generally smaller and have lower meat recoveries. (These data are based on a limited experimental trawl fishery in 1986–87.) Furthermore, if animals move upwards into the more productive shallow water when populations are thinned by fishing, then initial population responses to harvest may be masked. This phenomenon may also limit our ability to measure effects from experimental fishing.

An issue of concern is the concentration of annual fishing effort in relatively small areas, leading to localized depletion of sea cucumber stocks. Whether this is a serious issue is unknown, however sea cucumber populations may be fairly tolerant of small-scale depletion because the larval stage is protracted and recruitment likely widespread. Sea cucumber Quota Management Areas are being broken progressively into smaller parcels with the intention of distributing the effort more evenly within open areas.

Outlook

With over 50 per cent of the B.C. coast closed to commercial harvest, there is presently no risk of overall stock collapse. The initial expansion in landings and effort has been curtailed, and annual quotas are closely adhered to through the port validation of all landings.

Localized removal of these detritus feeders may have an impact on sea-bed ecosystems, but the importance of this ecological niche has not been investigated for the giant red sea cucumber in B.C..

GLOSSARY

Abundance	Weight or number of fish which make up a stock or species.
Aggregate	Group of populations which make up a stock for management purposes.
Anadromous fish	Species that are born in freshwater streams, rivers or lakes, spend their adult phase in the ocean, and return to their natal waters to spawn.
Assessment	Evaluation of a stock's productivity and ecological status.
Bycatch	Species unintentionally caught in fisheries directed at another species.
Catch per unit effort	A measurement of the mass of fish caught for a given amount of energy and resources expended by a fishing fleet.
Coded-wire tags	Small pieces of magnetized steel inserted in the nasal cartilage, with a binary code inscribed on the tags. A coastwide mark-recovery program allows the systematic recovery of tags in nearly all ocean commercial and recreational fisheries. The information allows researchers to estimate the catch and its distribution for tagged populations.

Diadromous	Species that divide their lives between freshwater and ocean environments.
Directed fishery	Fishery devoted to catching a particular species.
Enumeration	The act of counting fish returning to spawn.
Escapement (returns)	The number of mature salmon that pass through (or escape) the fisheries and return to their rivers of origin to spawn.
Exploitation rate	The percentage of a fish population that are caught by all fisheries combined. For example, if 650,000 fish were caught out of a population of 1 million fish, the exploitation rate would be 0.65 or 65 per cent.
Ex-vessel	Price for fish paid to fishermen, similar to wholesale value.
Fry	Newly hatched fish.
Jacks	Juvenile salmon that return to spawning grounds after one winter, or a year earlier than other members of a stock.
Limnological	Concerning lake and other fresh waters.
Mark-recapture	A method of estimating fish population size by marking a number of individuals then re-sampling the stock at a later date.
Marine survival rate	Portion of a population that survives during the open-ocean phase.
Mortality reference point F0.1	The point at which the slope of the yield-per-recruit curve as a function of fishing mortality rate is 10 per cent of its pre-fishing value.

Otolith	A bone-like structure found in the inner ear of many species of fish that allows scientists to estimate age.
Pelagic	Belonging to the upper layers of the open sea.
Population	Generally, a population consists of fish of a single species that spawn in the same stream or reach within a stream. They exhibit similar life history traits and are adapted to the habitats they occupy.
Regime (shift)	A fairly consistent and stable pattern in such factors as atmospheric pressure or sea-surface temperatures.
Smolt	Young fish entering the first stage of their migration.
Selective fishery	A conservation-oriented management approach which allows for the harvest of surplus target species or stocks while aiming to minimize or avoid the harvest of species or stocks of conservation concern.
Stock	An aggregate of populations of a single species that are grouped for management purposes. They generally have similar migration patterns and run timing.
Terminal area	A fishery location usually near freshwater (usually the mouth of rivers or bays) where the targeted species or stock has separated from other stocks that are mixed with it in more seaward fishing locations.

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Graphic Design and Art Direction:
Proximity Design Group Inc., Vancouver

Illustrations: D.R. Harriott
Source: Pacific Fishes of Canada, by J.L. Hart
Fisheries Research Board of Canada
Bulletin 180; Ottawa, 1973; FS 94–180

except Pink and Spiny Scallops
Source: Scallops: Biology, Ecology and Aquaculture, edited by Sandra E. Shumway
Elsevier Science Publishing Company Inc.
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